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**Remedial Investigation  
Report  
12686**

**Sturgis Well Field  
Remedial Investigation/  
Feasibility Study  
Sturgis, Michigan  
Volume 1 of 5**

Prepared for:  
**Michigan Department of Natural Resources  
Lansing, Michigan**

Prepared by:  
**Warzyn Inc.  
Madison, Wisconsin**

**March 1991**

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Remedial Investigation/  
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**REMEDIAL INVESTIGATION REPORT  
STURGIS WELL FIELD  
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## **EXECUTIVE SUMMARY**

### **INTRODUCTION**

This report presents the methods and results of the Remedial Investigation (RI) for the City of Sturgis Well Field (the Site). Warzyn Inc. was contracted to perform the Remedial Investigation/Feasibility Study (RI/FS) by the State of Michigan Department of Natural Resources (MDNR) under Contract 3644. The primary purpose of the RI included the identification of potential sources of contamination to the municipal wells in the City of Sturgis (the City), and the determination of the extent and migration routes of contamination within the aquifers underlying the City. The RI achieved these objectives, as outlined below.

The City uses five municipal wells which provide water to approximately 10,000 City residents. The City also supplies water to several businesses, industries and service institutions. In 1982, during routine chemical testing of the municipal water supply, the Michigan Department of Public Health (MDPH) identified the presence of two volatile organic compounds (VOCs) in the municipal water supply; trichloroethene (TCE; 4 to 10.3 ug/L) and tetrachloroethene (PCE; not detected to 1 ug/L). TCE and PCE are organic solvents commonly used as degreasing or cleaning agents in dry cleaning, metal fabrication and other industrial or commercial applications. The two affected wells were the Jackson and Layne wells (PW1 and PW2), located in the center of the City as shown in Drawing 12686-5. In October 1982, the City contracted with Gove Associates to attempt to identify the source of VOC contamination. By May 1983, Gove Associates had installed and sampled four wells, but were unable to locate the VOC plume or source. In November 1983, an industrial process well (R4) at Ross Laboratories on the north side of the City was found to contain detectable concentrations of TCE. By 1985, three of the five wells owned by Ross Laboratories (R1, R3 and R4) were found to be contaminated with VOCs. The types and concentrations of VOCs present in the Ross Laboratory groundwater samples were not made available during the course of the RI. In April 1984, the City began using groundwater pumped from the newly constructed Oaklawn well (PW5), located on the south side of Sturgis. Pumpage was discontinued at wells PW1 and PW2, except



for emergency needs, and increased at the Broadus Street and Lakeview wells (PW3 and PW4) to compensate for the loss of PW1 and PW2. Well PW3 is located on the westside, and well PW4 is located on the southeast side of Sturgis, respectively. However, in January 1985, TCE was detected by MDPH at or above proposed drinking water standards in well PW3 (3 to 6 ug/L). Therefore, regular use of this well was decreased, such that PW3 would also be used only in cases of emergency. Until recently, the City relied on wells PW4 and PW5 to supply water needs to local consumers. In February and March 1989, the City drilled and tested a new municipal well (Thurston Woods; PW6) located on the northeast side of Sturgis; it became operational in June 1989. See Drawing 12686-B1 for approximate well locations.

### **REMEDIAL INVESTIGATION FRAMEWORK**

Little information regarding the geology, vertical and horizontal distribution of the groundwater contamination plume, potential source areas and the nature and extent of contamination was available prior to the RI. Activities conducted during the RI proceeded through three phases of work (Phase I, Phase II, and Phase IIB).

Phase I was performed in the fall of 1987 and consisted of:

- Preparation of a Work Plan;
- An industrial survey;
- Two rounds of groundwater sampling;
- One round of surface water and sediment sampling;
- Soil gas sampling;
- Preliminary groundwater flow modeling;
- Drilling and well installation;
- Water level measurements;
- Hydraulic conductivity measurements; and
- Preparation of a technical memorandum.

Phase II, performed during the summer of 1988, included:

- Preparation of a Work Plan;
- One round of groundwater sampling;
- Soil gas sampling;
- Preliminary groundwater flow modeling;
- Soil boring, and well drilling and installation;
- Water level measurements;
- Hydraulic conductivity tests; and
- Preparation of a technical memorandum.

Work elements performed in Phase IIB during the spring and summer of 1989 were:

- Preparation of a Work Plan;
- One round of groundwater sampling;
- Additional groundwater flow modeling;
- Soil boring, well drilling and well installation;
- Water level and hydraulic conductivity measurements; and
- Preparation of a technical memorandum.

Discussion of the objectives of each phase of the RI are contained in the Work Plan documents and technical memoranda. These documents have been made available to the general public and are available for review at the site repository located in the Sturgis Public Library.

### INDUSTRIAL SURVEY

Based on a previous investigation by U.S. EPA, and sanitary discharge and other data provided by the City, several industries were surveyed to determine their general processes and current and past use of chlorinated solvents. The surveys were conducted at United Paper Inc., Walker-Bandholtz Paint Manufacturing Co., Frye Copy Systems, Kirsch Company Division of Cooper Industries, Sturgis Newport Business Forms, Abbott Laboratories Ross Division (Ross Labs), Sturgis Foundry Corporation and several other small industries. Based on the results of the survey, areas were selected for soil gas surveys to identify potential source areas. A narrative of the industrial surveys is contained in Appendix B.

## SOIL GAS SURVEY

Soil gas surveys were conducted in several potential volatile organic compound (VOC) source areas to identify locations for soil borings and monitoring wells to characterize these source areas. The field investigation relied on soil and water samples collected from monitoring locations and analyzed by on-Site gas chromatography (GC) to allow continual re-evaluation of monitoring well placement. Table 3-2 contains a summary of soil gas data.

## GEOLOGY AND HYDROGEOLOGY

The City overlies an area of complex glacial sediments. Several separate glacial till units interbedded with glacial outwash, occur in the subsurface of Sturgis. These units unconformably overlie shale bedrock, assumed to be the Mississippian Age Coldwater Shale.

Three till units were encountered, including an upper till unit, an intermediate depth till unit, and a deep till unit. Each till unit was separated by varying thicknesses of outwash deposits consisting of sand and sand and gravel. Till unit thickness varied from 90 ft to non-existent. Till units are overlain by outwash deposits of varying thickness. See Appendix C for well and soil boring logs, well construction details, and soil geotechnical results. Drawings 12686-15 through 12686-19 contain cross-sections of geologic conditions.

The City and Ross Laboratories production wells, screened in the lower outwash deposits, induce groundwater flow through the outwash deposits to one of these production wells. The till deposits, where present, restrict downward flow into the lower aquifer. The upper and lower aquifers are well connected in areas where the till is not present, allowing vertical contaminant migration.

Water table maps (Drawings 12686-7 through 12686-10) show a cone of depression which has a northwest/southeast orientation, and is caused by the absence of till layers and a good hydraulic connection between the lower and upper aquifers. This allows drawdown in the lower aquifer to be manifested in the upper aquifer, and for groundwater and contaminants to move from the upper aquifer to the lower aquifers through windows in the till units.

Potentiometric surface maps (Drawings 12686-11 through 12686-13) show the local groundwater flow direction in the lower aquifer below Sturgis is from northeast to southwest. Pumpage from municipal and industrial wells causes deviation from the local flow direction, and provides the mechanism to produce downward vertical gradients. Table 5-2 shows groundwater elevations determined during the RI; Table 5-3 contains calculated vertical groundwater gradients.

#### SITE CONTAMINATION

The primary contaminants found during the RI of the Site are trichloroethene (TCE) and tetrachloroethene (PCE). Contaminants migrated from at least three source areas to deep within the aquifer under the influence of local groundwater pumping. The RI did not find evidence of dense nonaqueous phase liquids (DNAPLs) during the groundwater or soil sampling investigation tasks.

The vertical distribution of contamination, as described in the RI report, extends from the water table to approximately 200 ft below the water table. The length of the VOC plume is in excess of 1 mile. Drawings 12686-6, 12686-20, 12686-26, and 12686-27 show the distribution of the total chlorinated ethenes.

Soil borings and monitoring wells were placed on three potential VOC source areas. Analytical results of soil (Appendix F) and groundwater samples (Appendix E) collected from these locations show soils from these locations are potential sources of continuing groundwater contamination.

Groundwater sampling shows substantial contamination beneath Kirsch Co. Plant No. 1, and Wade Electric. Well W26S and well nest W2D, downgradient of Kirsch Co. Plant No. 1, contain VOC concentrations in excess of 10,000 ug/L. The vertical contaminant profile at the Wade Electric location showed a relatively uniform VOC distribution with most concentrations ranging from 10 to 100 ug/kg in the source area (630 ug/kg PCE maximum). The bulk of the contamination may have already moved into the aquifer from this source at the time the full investigation began. The source of contamination at Wade Electric is the area of the former underground storage tanks. Soil contamination

at Telemark Business Forms, characterized from samples obtained from the boring for well W10S, showed low levels of TCE (ND to 2 ug/kg) and isolated PCE contamination (110 ug/kg to a depth of 5 ft and concentrations ranging from ND to 23 ug/kg for the remainder of the boring). Groundwater sampling suggests that groundwater impacts from Telemark Business Forms are localized.

### GROUNDWATER FLOW MODELING

A groundwater flow model was developed using the USGS Three Dimensional Finite Difference Groundwater Flow Model (MODFLOW). The groundwater flow model developed for the area confirmed observations made regarding groundwater flow direction (Drawings 12686-23 and 12686-24). The advective particle tracking model, coupled to the flow model, showed potential travel path directions for non-dispersive, non-reactive solutes entering the flow system at discrete locations and time intervals (Drawing 12686-25), and helped to reinforce observations regarding the areal and vertical extent of contamination.

### BASELINE RISK ASSESSMENT

The purpose of the Baseline Risk Assessment was to characterize the nature and estimate the magnitude of potential health and risks to public health and the environment which may occur due to exposure to contaminants identified at the Site. Chemicals of potential concern (Table 10-2) were selected based on their presence in media in comparison to background concentrations of the chemicals. Estimates of exposure to the chemicals in contaminated media were estimated for each source area based on current Site conditions, as well as potential future Site conditions. Cancer risk exposure scenarios based on current land use conditions (Tables 10-7, 10-8, 10-9) included:

- Exposure of City residents to bis(2-ethylhexyl)phthalate contaminated municipal water by drinking and through dermal adsorption while bathing ( $3 \times 10^{-6}$ ).
- Exposure of children to PAH and VOC contaminated surface soils through incidental ingestion and dermal adsorption while playing in source areas ( $2 \times 10^{-5}$  at Kirsch Co. Plant No. 1;  $2 \times 10^{-6}$  at Wade Electric; and  $2 \times 10^{-10}$  at Telemark Business Forms).
- Exposure of City residents to volatile contaminants in ambient air released from soils ( $7 \times 10^{-6}$  at Kirsch Co. Plant No. 1;  $1 \times 10^{-7}$  at Wade Electric; and  $4 \times 10^{-10}$  at Telemark Business Forms).

Cancer risk exposure scenarios based on potential future land use conditions (Tables 10-10, 10-11) include:

- Exposure of future residents to contaminated groundwater resulting from either installation of a well within the contaminant plume or by migration of groundwater contaminants to existing wells. Exposure may occur through drinking and dermal absorption. Contamination concentrations are assumed to exist in the future as under current conditions ( $6 \times 10^{-3}$ ).
- Exposure of individuals to PAH and VOC contaminated soils at a future residence developed at the source areas. Exposures may occur through incidental ingestion of soil and dermal adsorption. It is assumed contaminants in either surface or subsurface soils at current concentrations are made available for exposure as a result of Site development ( $5 \times 10^{-4}$  at Kirsch Co. Plant No. 1;  $7 \times 10^{-5}$  at Wade Electric; and  $3 \times 10^{-8}$  at Telemark Business Forms).

The objective of the environmental assessment was to characterize the natural habitats which may be influenced by the Site, and to appraise the actual or potential adverse effects contaminants have on these habitats. Identified contamination is within the City of Sturgis, and in areas not containing sensitive habitats. For this reason, ecological effects are not anticipated.

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**DRAFT REMEDIAL INVESTIGATION REPORT  
STURGIS WELL FIELD  
STURGIS, MICHIGAN**

**1.0 INTRODUCTION**

**1.1 AUTHORIZATION**

This report presents the methods and results of the Remedial Investigation (RI) for the City of Sturgis Well Field (the Site). The Site was ranked and is listed by the U.S. Environmental Protection Agency (U.S. EPA) on the National Priorities List (NPL). This study was conducted in compliance with and to satisfy the U.S. EPA Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), Superfund Amendments and Reauthorization Act of 1986 (SARA) programs and the National Contingency Plan (NCP). The Site received a hazard ranking system (HRS) score of 42.24 on May 23, 1983 by U.S. EPA. The Site was included on the National Priorities List (NPL) on September 21, 1984 with a state rank of 47, based on the HRS score and a State of Michigan Act 307 score of 820. Warzyn Inc. (Warzyn) was contracted to perform the Remedial Investigation/Feasibility Study (RI/FS) by the State of Michigan Department of Natural Resources (MDNR) under Contract 3644.

**1.2 PURPOSE AND OBJECTIVES**

The primary purpose of the RI included the identification of potential sources of contamination to the municipal wells in the City of Sturgis (the City), and the determination of the extent and migration routes of contamination within the aquifers underlying the City. Objectives of the RI included collection of sufficient data to support the evaluation of threats to the public health and welfare in the Endangerment Assessment (EA) and provide data to support the development of remedial responses to the well field contamination within the context of the FS.

To achieve the RI objectives, three field investigation phases were performed (Phase I, Phase II and Phase IIB), which included identification of potential source areas within the City, survey of the chemicals and processes of industries identified as potential source areas in the City, and an extensive study of the soil and groundwater conditions in the City.

Section 3 contains a detailed description of the phased investigation program.

### **1.3 ORGANIZATION OF THE REPORT**

Volume 1 of the RI report is organized into 10 chapters. The first two chapters discuss background information which provides the basis for the RI, including:

- Section 1 - Introduction
- Section 2 - Site History

The following three chapters discuss investigative measures and the local site setting:

- Section 3 - Remedial Investigation Activities
- Section 4 - Regional Setting
- Section 5 - Physical Description of the Site

The succeeding two chapters include results of the chemical evaluation of the media including:

- Section 6 - Data Validation
- Section 7 - Contaminant Characterization

The final three chapters include interpretations of Site conditions and results of the RI:

- Section 8 - Contamination Fate and Transport
- Section 9 - Groundwater Modeling
- Section 10 - Summary and Conclusions

Volume 1 also contains Tables, and Figures. Volume 2 of the RI report contains Drawings. Volume 3 of the RI report contains Appendices A through C. Volume 4 of the RI report contains Appendices D through G. Volume 5 of the report contains Appendix H. See the Table of Contents in each volume of the report for a listing of the headings contained in this report.

## **2.0 SITE HISTORY**

### **2.1 NATURE OF PROBLEM AND HISTORY OF RESPONSE ACTIONS**

The City (Drawing 12686-B1) provides water to approximately 10,000 City residents. The City also supplies water to several businesses, industries and service institutions. In 1982, during routine chemical testing of the municipal water supply, the Michigan Department of Public Health (MDPH) identified the presence of two volatile organic compounds (VOCs) in the municipal water supply. The identified VOCs were trichloroethene (TCE) and tetrachloroethene (PCE). TCE and PCE are organic solvents commonly used as degreasing or cleaning agents in dry cleaning, metal fabrication and other industrial or commercial applications. The two affected wells were wells PW1 and PW2 (Drawing 12686-B1).

Water samples had been collected from the City production wells since 1955 for analysis of inorganic constituents by the MDPH on an irregular basis (Table 2-1). However, VOC analysis was first performed in June 1982, and TCE was detected in samples from wells PW1 and PW2. Since then, the production wells remaining in use have been sampled by MDPH and/or MDNR at least on a yearly basis for VOCs and indicator parameters.

In August and September 1982, MDPH suggested that the City discontinue using the two contaminated municipal wells, undertake an investigation in an attempt to locate the source of VOC contamination, and explore the possibility of locating alternate well field sites. In October 1982, the City initiated attempts to identify the VOC source area and commissioned Gove Associates to identify the source of contamination. In December 1982, the City began the process of identifying additional well field sites. A rise in TCE and PCE was noted in samples collected by MDPH from wells PW1 and PW2 between 1982 and 1983. Between June 1982 and May 1983, TCE concentrations in well PW1 continuously increased (with the exception of the August 20, 1982, sample) from 26 ug/L to 152 ug/L, while TCE at well PW2 fluctuated between 2 ug/L and 43 ug/L during the same period. PCE was detected only at the PW1 well and increased from a concentration of 1 ug/L to 3 ug/L between September 1982 and May 1983. Pumping at these wells was stopped in 1983. By May 1983, the VOC source area investigation by Gove Associates had ended with the City unable to locate the contamination source or plume. The City



then decided to increase the pumping capacity of its remaining two wells, wells PW3 and PW4. No VOCs were detected in samples from well PW3 between May and December 1983. During this period, the pumping of well PW3 was increased to replace the lost production from wells PW1 and PW2. Well PW3 provided approximately 50% of the water supply by 1984 (approximately one million gallons per day).

In November 1983, an industrial process well (R4) at Ross Laboratories on the north side of the City was found to contain detectable concentrations of TCE. By 1985 three of the five wells owned by Ross Laboratories (R1, R3 and R4) were contaminated with VOCs. This problem area has been referred to as the W. Lafayette Street Area in MDNR records. The industry responded by installing a new well north of the plant (well R5). Although the new well has no detectable VOCs, the industry is using carbon adsorption treatment (based on discussions with the plant engineer) for water which is used for consumption and as ingredient water in their manufacturing process.

In April 1984, the City began using groundwater pumped from the newly constructed Oaklawn well (PW5). Pumpage was discontinued at wells PW1 and PW2, except for emergency needs, and increased at wells PW3 and PW4 to compensate for the loss of PW1 and PW2. In June 1984 U.S. EPA Region V issued a confidential report detailing research into the identity of potential responsible parties (PRPs) for the Site contamination. Included in the report was a description of source of information, Site background information, locations of former landfill sites, possible waste generators and a chronology of dry cleaner and manufacturing facilities located in Sturgis since approximately 1900. The report provided Warzyn was the basis for conducting the industrial survey and Phase I of the RI.

In January 1985, TCE was detected at or above proposed drinking water standards in well PW3. The concentration fluctuated between 1 ug/L and 6 ug/L at well PW 3 between January 1985 and May 1986. Groundwater flow and contaminants may have moved from one well to another, as the center of pumping was shifted from wells PW1 and PW2 to well PW3. Therefore, use of this well was decreased, such that PW3 would be used only in cases of emergency.

The concentrations of inorganic chemical constituents in individual municipal wells have remained relatively unchanged through time. However, data provided by the City shows that the chemistry of the groundwater in wells in the central part of the City (the Jackson, Layne and Broadus Street wells) differs somewhat from wells in the southern part of the City (the Lakeview and Oaklawn wells). Chloride (13 to 20 mg/L), nitrate (38 to 51 mg/L expressed as nitrogen), sulfate (38 to 51 mg/L) and hardness (315 to 319 mg/L) concentrations are higher in the central wells than they are in the southern wells (Cl: 4 to 8 mg/L; NO<sub>3</sub>-N: 0 to 1 mg/L; SO<sub>4</sub>: 22 to 32 mg/L; hardness: 278 to 309 mg/L). Other inorganic parameters (pH, conductivity, alkalinity, calcium, magnesium, sodium, and potassium) are similar at the respective locations.

In addition to TCE and PCE, MDPH has identified bromoform and other trihalomethanes in the water supply. These compounds are probably the result of in-line chlorination of the drinking water supply.

In August 1986, Warzyn Engineering Inc., began the RI/FS of the Site, under the auspices of MDNR. The information provided herein results from a field investigation conducted between August 1987 and January 1990.

Until recently, the City relied on wells PW4 and PW5 to supply water needs to local consumers. In February and March 1989, the City drilled and tested a new municipal well location. The Thurston Woods well (PW6) became operational in June 1989.

## 2.2 MUNICIPAL WATER SUPPLY SYSTEM

As summarized above, the City water supply system consists of one abandoned and five active wells (Drawing 12686-B1). Wells PW1 and PW2 are the oldest wells in the City system, and are located on the [REDACTED]

[REDACTED] Both wells were constructed c.1923, to identical specifications, approximately 156 ft deep. One well was designed as a primary well, while the second well was intended as a backup well. It is not clear which well served which function. Well PW2 currently serves as the second backup well in the municipal system. Well PW1 was abandoned with concrete by the City between 1985 and 1986, due to TCE contamination.

Well PW3, formerly known as the Kirsch well, is located on the [REDACTED]. The well was completed in November 1956, to a depth of 203 ft. Well PW3 functions as the first backup well in the current municipal system. The City currently plans to implement treatment for VOCs at well PW3.

Well PW4, constructed in 1952, is one of three remaining primary wells serving the water supply needs for the City. Located on the [REDACTED] well PW4 was installed to a depth of approximately 159 ft. Although previous sampling showed that well PW4 was not contaminated, the fourth groundwater sampling round (August 1989) performed during the RI detected low level contamination (1 ug/L of TCE).

Well PW5 is located in [REDACTED]. Well PW5 was installed in 1984, to a depth of 141 ft. Although reportedly installed in close proximity to a former landfill site, well PW5 has remained free of VOC detections, and currently serves the City as the primary well in the system.

Well PW6 was installed in February 1989, and went into service during June 1989. Well PW6 was drilled to a depth of 180 ft. Water samples collected during well efficiency tests showed no detection of VOCs. According to the City Engineer, well PW6, located in [REDACTED], will eventually function as the primary City well.

### 2.3 INDUSTRIAL WATER SUPPLY

Based on information collected during the RI, Ross Laboratories and Sturgis Foundry Corporation are the only two industries identified to have functional production well systems in the City. Although Kirsch Co. Plant No. 1 has two wells and Kirsch Co. Plant No. 2 has one well, none of these wells currently function as water supply wells. The well at Kirsch Co. Plant No. 2 is kept as a fire fighting water supply well. Based on discussion with plant representatives, the two wells at Kirsch Co. Plant No. 1 are not being used, and are not believed by them to be functional.

The water supply at Ross Laboratories, located at the intersection of Lafayette Street and Centerville Road, consists of five pumping wells. Constructed in 1947, wells R1 and R2 were the original water supply wells for Ross Laboratories, formerly known as M & R Dietetic. As manufacturing operations grew, well R3 was added in 1958, to augment the industrial water supply demand. Well R4 was added to the system in 1981, and became one of the primary wells in the system. Well R5 was added to the system in 1985, and became the primary well for food product production. Currently, groundwater from well R5 is treated using activated carbon prior to use in food production. Wells R1, R3 and R4 have been contaminated with VOCs, and serve to produce groundwater used for non-contact purposes, such as cooling water. Well R4 was taken out of regular service in December 1987. Wells R1 through R3 remain on-line, and may serve to block or retard VOC migration toward well R5. Wells R1 through R4 are located on the grounds of Ross Laboratories. Well R5 is located north of the Sturgis airport.

Well F1 is located on the Sturgis Foundry Corporation property. Installed in 1985, well F1 was used to provide non-contact cooling water for the foundry operations. Well F1, as determined by infield gas chromatography methods during Phase I groundwater sampling for this RI, was identified as contaminated by VOCs. Groundwater from F1 contained 95 ug/L TCE. After using this water for cooling purposes, some of the VOCs may have volatilized as the surface water from the Sturgis Foundry discharge lagoon contained 5 ug/L TCE.

Pumping from well F-1 was discontinued in December 1988 (Verbal Communication with Sturgis Foundry Plant Engineer).

### **3.0 STAGING AND PURPOSE OF TASKS**

#### **3.1 INTRODUCTION**

Methods used to obtain data during the RI are summarized below. Expanded discussion of the RI field methods is contained in Appendix B. Results of the RI are contained in Sections 5, 7, 8, 10 and 11. The remedial investigation consisted of:

- An industrial survey (Phase I);
- Sampling and analysis of existing wells, and surface water/sediment sampling from gravel pits at three locations prior to Phase I RI drilling activities (Round 1 sampling);
- Soil gas surveys; (Phase I and II)
- Well installation and sampling/analysis programs during drilling (Phases I, II and IIB);
- Soil boring programs (Phases II and IIB);
- Three rounds of groundwater quality sampling during execution of the RI (Rounds 2, 3 and 4) (Phase I, II and IIB, respectively);
- Groundwater level measurements (Phases I, II and IIB);
- Hydraulic conductivity tests (Phases I, II and IIB);
- Well location and elevation surveys (Phases I, II and IIB); and
- Groundwater flow modeling (Phases I, II and IIB).

Little or no information regarding the vertical and horizontal distribution of the groundwater contamination plume or potential source areas was available upon initiation of the Phase I field investigation. Similarly, limited geologic information was available. To compensate for the lack of geologic and geochemical data, the field investigation relied on sampling and on-Site chemical analysis to allow continual re-evaluation of monitoring well placement. A soil gas survey was conducted to evaluate several potential volatile organic compound (VOC) source areas. Water quality sampling was performed on existing wells, and soil and water quality samples were collected and analyzed during drilling in an attempt to aid identification of vertical and horizontal zones of contamination in the aquifers underlying the City.

A Site trailer was located at the City waste water treatment plant and was used as a base of operations for the project. The trailer housed a gas chromatograph (GC) in one room and the Site operations headquarters in a separate room. The fenced wastewater treatment plant provided a secure area for storage of well construction materials, sample bottles, coolers, and geotechnical equipment required for the field investigation. The decontamination station for the drilling rig, associated tools and well construction materials was an existing concrete pad with a sanitary sewer. The pad was cleared of materials, and was steam cleaned prior to use in each phase of the investigation.

### 3.1.1 Industrial Survey

A survey of several industries was conducted in 1986 prior to initiation of Phase I field activities in an attempt to secure additional information pertaining to current and past use of chlorinated solvents, and to obtain knowledge of the general industrial processes and practices of the facilities. The surveys were conducted by Warzyn. The MDNR hydrogeologist and project manager accompanied the Warzyn team during several of the surveys.

The surveys were conducted at United Paper Inc., Walker-Bandholtz Paint Manufacturing Co., Frye Copy Systems, Kirsch Company Division of Cooper Industries, Sturgis Newport Business Forms, Abbott Laboratories Ross Division (Ross Labs), Sturgis Foundry Corporation, and several other small industries. These facilities were selected for inspection based on U.S. EPA's search for Potentially Responsible Parties (PRPs), review of the City of Sturgis Sewage Treatment Plant's survey of non-domestic sewer discharges, and the proximity of the facilities to the affected municipal water supply wells. Appendix B contains a detailed discussion of observations made during the survey visits.

### 3.1.2 Soil Gas, Soil and Groundwater Analysis During Drilling

In preparation for each phase of the field investigation program, a laboratory GC was mobilized to the City for the purpose of analysis of soil gas, water quality, and/or soil samples for VOCs. Samples collected during drilling were intended to provide for detection and preliminary qualification of the following compounds:

- benzene
- bromodichloromethane
- bromoform
- chloroform
- chlorodibromomethane
- 1,1-dichloroethane
- 1,2-dichloroethane
- 1,1-dichloroethene\*
- 1,2-dichloroethenes\*
- ethyl benzene
- methylene chloride
- tetrachloroethene\*
- toluene\*
- 1,1,1-trichloroethane
- trichloroethene\*

**\* Target Compounds**

The purpose for on-Site GC analysis of soil and water headspace was to identify potential source areas for VOC contaminants, and to help optimize well screen locations.

Sample results, standard conditions, and notes were recorded in bound log books. Field results of GC analyses were considered tentatively identified with estimated concentrations. Additional details regarding analytical procedures are contained in Appendix B.

**3.1.3 Groundwater Quality Sampling - Pre-existing Wells (Round 1)**

In order to obtain current data on existing Site conditions and the nature and extent of VOCs, samples were collected from existing groundwater supply and monitoring wells in Sturgis at the beginning of the Phase I field investigation. Samples were collected from a total of 28 wells (see Drawing 12686-5 for well locations), including:

- 7 existing monitoring wells installed for Ross Labs (MW1A, MW1B, MW1C, MW2B, MW2C, MW3A and MW3C);
- 4 existing monitoring wells installed for Sturgis Foundry Corporation (GW1, GW2, MW4 and MW6);
- 4 existing monitoring wells installed by Gove Associates for the City (GW3, GW4, GW7 and GW8);
- 2 test wells installed for the City (TW83A and TW84A);

- 5 industrial process wells located at Ross Labs (R1 through R5);
- 1 industrial process well located at Sturgis Foundry Corporation (F1);
- 4 municipal wells installed for the City (PW2, PW3, PW4 and PW5); and
- 1 private well at A.W. Ayers Insurance Co. (used for a heat pump heating and cooling system)(A-1).

In addition to groundwater sample collection at each monitoring well, depths-to-water and total well depths were measured at monitoring wells and compared to as-built well depths to establish well identity. Depths-to-water were measured prior to sampling with an electronic water level indicator, or a measuring tape with a sounding device attached to it. Sample collection procedures are discussed further in Appendix B. Table 3-1 shows the analyses performed for this task. Appendix E contains analytical results. The Phase I Technical Memorandum contains additional information on Round 1 Sampling.

#### 3.1.4 Surface Water and Sediment Quality Sampling

Surface water and sediment samples were collected concurrent with Round 1 groundwater samples by the groundwater sampling team. Samples were collected from gravel pits, used as storm runoff or effluent discharge points, at Ross Labs, Kirsch Co. Plant No. 2, and Sturgis Foundry Corporation.

Surface water and sediment samples were collected to assess potential impacts of industrial processes on surface water and subsequently on groundwater by recharge of the aquifer by surface water, and to evaluate potential remedial actions. The collection of surface water and sediment samples supplemented groundwater data collected from adjacent wells. Sample collection procedures are discussed in Appendix B. Samples were analyzed for CLP VOCs. Appendix E contains analytical results. Further discussion of surface water and sediment sampling is also presented in the Phase I Technical Memorandum.

#### 3.1.5 Soil Gas Sampling

Phase I soil gas sampling with on-Site analysis of samples was conducted (185 sampling points in 23 areas) to help identify potential VOC source areas, and to possibly assist in locating the VOC plume present at the water table in the vicinity of source areas. Phase II soil gas sampling with on-Site analysis of samples (117 sampling points in 6 areas)



served to further quantify the Phase I results, and investigate other potential source areas. The number of actual sampling points exceeded the Work Plan projections by 103 in Phase I and by 67 in Phase II, due to the unanticipated size and extent of identified source areas.

The soil gas survey conducted at each location was based on the size of the facility, the type of operation conducted at the facility, and the results of the industrial surveys. The facilities investigated in the soil gas survey were metal fabricators, a food processor, printers, City right-of-ways, a City park suggested to be a former landfill, a foundry and the City airport. Results are included in Table 3-2. Sample collection procedures and analyses are discussed further in Appendix B. Drawing Number 12686-B2 shows the locations of soil gas probes at Kirsch Co. Plant No. 1. Soil gas sampling locations are discussed further in the Technical Memoranda prepared for Phases I (Phase I Tech Memo Appendix D) and II (Phase II Tech Memo pages 5 through 6).

#### 3.1.6 Monitoring Well Installation

Seventeen groundwater monitoring wells (Drawing 12686-5) were installed at eleven locations during performance of Phase I drilling. At four locations (W1, W6, W7 and W8) nests of two wells were installed, while at one location (W2) a nest of three wells was installed. Single wells were installed at three locations to function as second wells at a nest where a pre-existing well existed. Single wells were also placed in three locations to serve as water table wells. Each deep well was gamma logged upon reaching the terminus of the boring (Appendix D). For additional details regarding Phase I drilling, refer to the Phase I Technical Memorandum.

Thirty-seven Phase II wells (Drawings 12686-5) were installed at 27 locations to further characterize groundwater quality and enhance the Phase I interpretations of geologic conditions. Single wells were installed at two locations (W11D and W18I) to function as second wells in a well nest. Sixteen wells were installed as single water table wells. One well (W37I) was installed as a single well piezometer. Nests of three wells were installed at two locations (W26 and W27). Nests of two wells were installed at six locations (W28,

W29, W30, W34, W35 and W36). After consultation with MDNR, two additional wells were installed during Phase II to replace previously damaged wells (W3SR and W2DR). Well W2DR was drilled deeper than specified in the Phase II work plan to profile a VOC plume in the aquifer. See the Phase II Technical Memorandum for additional details

Nine Phase IIB wells (Drawing 12686-5) were installed at five locations to further refine the water table, and provide geologic data to a depth of approximately 250 ft below ground surface. The rationale for drilling below the elevation of the municipal wells lies with the discovery of high concentrations (over 1,000 ppb) of VOCs during drilling at Phase II well W2DR. Well W5DD served to form a nest of three wells at its respective location. Well (W42S) was installed to observe water table conditions at a suspected VOC source area. One well (W32D) was installed to track a VOC plume from a suspected source area to a downgradient position. Nests of two wells were also installed at three locations (W39, W40, W41). One well was installed to replace a previously damaged well (W34SR). After consultation with MDNR, the total number of Phase IIB wells was reduced due to unforeseen changes in geologic conditions, which included difficult drilling due to extremely dense till units discovered below previously explored depths, and runny sands which lengthened the time required to collect water samples during drilling. Refer to the Phase IIB Technical Memorandum for additional discussions regarding well installations.

Monitoring wells were installed to provide data on aquifer characteristics, groundwater quality, and groundwater flow directions. Groundwater from deep wells were sampled at pre-determined depths during drilling, and analyzed on-Site with a GC to characterize the vertical distribution and nature of contaminants present within the aquifer, and to optimize the vertical location of the well screen. The nested wells provide information on vertical groundwater gradients and water quality at depth in the aquifer. Well nests generally included a shallow water table well, installed in the upper aquifer, and a deep piezometer, installed in a lower aquifer. Intermediate depth wells were installed to monitor known groundwater contamination at specific depths. Discussions of drilling

methods and problems encountered during drilling, and well development are contained in Appendix B. Boring logs and well construction details are contained in Appendix C. Gamma logs are contained in Appendix D.

#### 3.1.7 Soil Boring

Eighteen Phase II and four Phase IIB soil borings were performed during the RI in areas identified as potential source areas, to characterize areal distribution of VOCs. Locations of the borings were based on analyses of soil gas samples, soil samples collected and analyzed during well installation, and groundwater samples. Twelve soil borings (eight Phase II and four Phase IIB) were performed at Kirsch Co. Plant No. 1, five soil borings (Phase II) were performed at the former Wade Electric facility, and five soil borings (Phase II) were performed at Telemark Business Forms. Drawing 12686-21 shows soil boring locations. Sampling methods are discussed in Appendix B. Table 3-3 shows the analyses performed for this task. Appendix C-3 contains soil boring logs. See Phase II and IIB Technical Memoranda for additional information.

Surface soil samples were collected from each of the three source areas (Kirsch Co. Plant No. 1, Wade Electric Co. and Telemark Business Forms) to characterize the potential contamination at each of these properties. The locations of the surface soil samples are shown on Drawings 70084-B8, -9 and -10. The soil samples were analyzed for Target Compound List organic chemicals and Target Analyte List metals and cyanide in accordance with Contract Laboratory Program procedures.

#### 3.1.8 Additional Groundwater Quality Sampling (Rounds 2, 3 and 4)

Round 2 groundwater samples were collected from the 28 pre-existing wells and the 17 Phase I wells (45 total) approximately 1 month after the conclusion of the Phase I drilling program. Round 3 groundwater samples were collected from 26 pre-existing wells, 15 Phase I wells and 37 Phase II wells (78 total) approximately 1 month after the conclusion of the Phase II drilling program. Round 4 groundwater samples were collected from 5 municipal wells, 20 Phase II wells and 9 Phase IIB wells (34 total) approximately 1 month after concluding the Phase IIB drilling program. Sampling procedures and analytical parameters were consistent with procedures and analyses used during Round 1 sampling.

See Appendix B for further discussion of procedures and parameters. Table 3-1 shows analyses performed for individual samples. See Technical Memoranda for Phases I, II, and IIB for additional discussion of Rounds 2, 3 and 4 sampling, respectively.

#### 3.1.9 Groundwater Level and Hydraulic Conductivity Measurements

Fifteen rounds of groundwater level measurements were performed during the course of the RI to determine gradients, thus ascertaining groundwater flow directions.

Hydraulic conductivity tests were performed in-situ on monitoring wells using single well drawdown methods. Data reduction was performed using the methods of Bouwer and Rice (1976). Appendix B contains details of the water level and hydraulic conductivity testing programs, Table 5-2 shows groundwater elevations of monitoring wells. These data are also contained in Technical Memoranda prepared for Phases I, II, and IIB. Drawings 12686-7 through 12686-13 are water table and potentiometric surface maps, respectively.

#### 3.1.10 Location and Elevation Survey

Well location and elevation surveys were performed during the RI, following each phase of the drilling program. Locations and elevations of the City and industrial production wells, test wells, and monitoring wells were determined. See Appendix B for additional survey methods and procedural descriptions, and Phases I, II, and IIB Technical Memoranda for additional discussions of each survey.

#### 3.1.11 Groundwater Modeling

A computer model was developed to simulate groundwater flow within the vicinity of the City. The initial purpose of the groundwater flow model was to examine potential groundwater flow directions under variable pumping rates, determine potential capture zones of pumping wells prior to and during the process of VOC contamination, and to examine aquifer parameters and locations most sensitive to groundwater flow direction and velocity. The model was also used as a qualitative tool between field investigation phases to help optimize areal distribution of the monitoring well network intended for succeeding field investigation phases. Aquifer parameters were progressively updated

throughout the RI as additional data became available. Refer to Section 9 of this report for additional discussion of the groundwater flow model development and implementation. The final use of the model will be to help evaluate remedial action alternatives.

## **4.0 REGIONAL SETTING**

### **4.1 LOCATION**

The City is located in south-central Michigan in St. Joseph County approximately 2 miles north of the Indiana State line, halfway between the Chicago and Detroit metropolitan areas. The majority of the City lies within the political confines of Sturgis Township, while northern, northeastern and eastern portions of the municipal area lie within Sherman, Burr Oak and Fawn River Townships, respectively. The City encompasses approximately 5 square miles, and approximately 10,000 people reside in the City. The City's economic base is largely industrial. Drawing 12686-B1 is a Site Location Map for the City of Sturgis.

### **4.2 REGIONAL GEOLOGY**

The City overlies an area of complex glacial sediments formed by three separate ice lobes (the Michigan Lobe, the Saginaw Lobe, and the Erie Lobe) that advanced and deposited till and associated outwash sediments in excess of 250 ft thick in the Site area. These ice advances occurred during the Woodfordian Substage of the Wisconsin Stage of continental glaciation approximately 12,000 to 19,000 years ago. Changes in the position of each ice lobe edge determined the types of glacial sediments deposited. The recessional moraines outline the positions of each ice lobe as it retreated the final time. These ice edge positions are topographically represented by an arc-shaped series of moraines (hilly topography) which intersect north of the Site (Drawing 12686-A8). Sediments associated with moraines located south and southwest of the Site are found relatively deep in the subsurface at the Site. Near subsurface sediments at the Site are primarily the result of outwash from Pleistocene glaciers located northeast and west of the Site.

The first glacial ice advance recorded by deposits in the area occurred in early Woodfordian time (12,000 - 19,000 years ago). This ice advanced into central Indiana and deposited tills and outwash, which in the Site form the lower till and outwash units. After deposition of these sediments, the ice lobes receded to positions north and west of the Site. During this time, the existing land surface was subjected to weathering and soil forming processes. Weathered soil and topsoil horizons were formed. Ice lobes then advanced to positions marked by the Middlebury and Lagrange Moraines (greater than

16,000 years ago) of the Saginaw Lobe, located south and southwest of the Site. Tills and outwash associated with these moraines were deposited in the Site on top of early Woodfordian deposits at intermediate to shallow depths (Monaghan, et al., 1986a, b).

The ice lobes again receded and re-advanced to positions directly north of the Site, marked by the Sturgis moraine (15,000 to 16,000 years ago) of the Saginaw Lobe. Surficial and near surface till and outwash units were deposited. Later recession and re-advance of the ice margin formed the Tekonsha Moraine (14,000 to 16,000 years ago) of the Lake Michigan and Saginaw Lobes, located west and northeast of the Site (Monaghan, et al., 1986a, b). Glacial meltwater from these ice lobes flowed through outwash channels trending to the southwest approximately 2 miles northwest of the Site, and trending southwest then bending south-southeast about 1 1/2 miles east of the Site.

The upper bedrock unit in the area is assumed to be the Coldwater Shale of the Kinderhookian Series, Mississippian in age. Site-specific geologic observations are discussed in Section 5.2.

#### 4.3 REGIONAL TOPOGRAPHY AND HYDROLOGY

The City of Sturgis lies on an outwash plain at the foot of three recessional moraines. Topographic relief within the confines of the City is very small, with maximum relief of approximately 40 ft. However, relief increases considerably as one moves to the northeast of northwest of the City into the morinal feature. Topography to the northeast and northwest of the City is somewhat hummocky with several lakes and wetland occupying the low lying areas. A surface water divide to the west and northwest of the City separates the Prairie River and Fawn River watersheds. Because of the relatively high permeability of soils in this area, rapid infiltration of precipitation can be expected.

Several surface water features are present within the vicinity of Sturgis. Approximately two miles to the south and east of the city lies the Fawn River which flows out of its headwaters, approximately 8 miles east of Sturgis, to its confluence with the St. Joseph

River approximately 70 miles away. Few minor surface water features are present within City limits, including absorption ponds at Ross Laboratories, Kirsch Co. Plant No. 2, and Sturgis Foundry Corp.; and the Nye Drain which drains the city's sewerage treatment plant outfall and south to the Fawn River. Absorption ponds at Sturgis Foundry Corp. and Kirsch Co. Plant No. 2 allow non-contact cooling water to infiltrate into the ground. The absorption pond at Ross Laboratories allows storm water run off to infiltrate into the ground (Drawing 12686-5).

Several large kettle lakes are present within the Sturgis Moraine, including Minnewaukan, Omena, Grey and Stewart Lakes. The margin of the Sturgis Moraine also contains significant wetland areas, typical of glaciated, deranged drainage systems. The wetland associated with Baker Lake, east of the City, is the largest wetland in the area, covering approximately 0.5 square miles. Each of the lakes along the margin of the Sturgis Moraine contains relatively large wetland areas surrounding and adjacent to the lake. Other wetlands of note are located southeast of the City along the Fawn River (Drawing 12686-B1).

#### 4.4 REGIONAL HYDROGEOLOGY

Other than the results of the RI described herein, there are no published, detailed studies of the hydrogeology or groundwater flow conditions in the Site area. However, based on groundwater levels in the City, the topography and locations of the surface water bodies described above, the City appears to be located on top of a groundwater high between the surface water bodies. In the absence of pumping, groundwater flow may be radially outward from the City. This probable pre-pumping condition was recreated in the groundwater flow model (see Section 9). Municipal and industrial pumping has created a cone of depression, which is superimposed on the water table and piezometric flow system. Therefore, there does not appear to be a strong influence of a regional gradient on the groundwater flow system.

As discussed above, the multi-layer aquifer system underlying the Site consists of thick sand and gravel sequences separated by low permeability till and/or lacustrine units. Although discontinuous in areal extent, these low permeability units likely serve to locally retard vertical groundwater flow. Municipal and industrial production wells pump



groundwater from the third sand and gravel deposit, located beneath two low permeability units which are separated by sand and gravel aquifers. Specific descriptions of the municipal and industrial water supply systems are contained in Section 2 of this report. Site-specific hydrogeology is discussed in Sections 5, 8, 9 and 10.

#### 4.5 CLIMATOLOGY

Total monthly precipitation in the vicinity of the Site ranges from 1.6 to 4.0 in., with total precipitation approximately 34 in. per year. The months of April through July are the wettest months of the year, averaging approximately 3.6 in. per month, while December through February average approximately 1.9 in. per month. Snowfall typically is greatest from January through March.

Average monthly temperatures fluctuate from approximately 23°F to 72°F. The annual monthly average is approximately 48°F. The months of June through September are warmest while December through February are the coolest.

## **5.0 PHYSICAL DESCRIPTION OF THE SITE**

### **5.1 LOCAL HYDROLOGY**

As described in Section 4 of this report, the City is located in the center of a surface water divide, with the Fawn River watershed to the south and east, and the Prairie River watershed to the north of the City. The Nye Drain, the closest natural surface water feature to the City, is a northeast to southwest flowing stream located within the southern half of the City. The Nye Drain changes from an intermittent to permanent stream at the discharge point from the City sewage treatment plant. The Nye Drain flows to the southwest and discharges to the Fawn River, approximately 2 miles south-southwest of the City.

The only other surface water bodies of note within the City limits, are located at Ross Labs, Sturgis Foundry Corporation, and Kirsch Co. Plant No. 2. Each of these surface water bodies resulted from previous excavation of sand and gravel deposits from these locations. The excavation on the Ross Labs property intersects the water table, and is currently used as a sedimentation basin to channel storm water runoff from the property. Conversely, the excavations located on the property of Kirsch Co. Plant No. 2 and Sturgis Foundry Corporation act as discharge points for non-contact cooling water used in manufacturing operations at the respective facilities. Discharges into these excavations are regulated by discharge permits.

### **5.2 GEOLOGY**

As stated in Section 4, the City overlies an area of complex glacial sediments derived from the Michigan Lobe, the Saginaw Lobe, and the Erie Lobe of the Woodfordian Substage of the Wisconsin stage of Pleistocene glaciation. Boring logs for wells installed in the City prior to initiation of the RI field investigation, and logs for soil borings and well installations performed for the Site RI are contained in Appendices C-3, C-4, C-1, respectively. These boring logs were used to construct six geologic cross-sections through the study area (Drawings 12686-15 through 19). These sections show the relationships between the glacial units within the unconsolidated stratigraphic sequence, and the underlying bedrock.

Several separate glacial till units and associated sand, gravel, silt and clay outwash units occur in the subsurface of the Site. These units unconformably overlie shale bedrock, assumed to be the Mississippian Age Coldwater Shale. The Coldwater Shale was encountered during RI drilling activities at wells W40D and W41D at elevations 670 and 652 ft above mean sea level (MSL) (approximately 251 and 259 ft below ground surface), respectively (cross-sections A-A' and C-C' on Drawings 12686-15 and 16). An indurated sand and gravel deposit, assumed to be Quaternary Age, forms a thin local deposit between the Coldwater Shale and the overlying glacial deposits. This indurated sand and gravel deposit was encountered during drilling at well location W40D.

Grain size analyses and Atterberg limits were determined for 17 soil samples, which included the various till and outwash units (Table 5 and Appendix D). Three till units were identified during the RI, including an upper or near surface till unit, an intermediate depth till unit, and a deep, or lower till unit. Each unit was separated by varying thicknesses of outwash deposits. For the purpose of this discussion, till is defined as a dense to very dense unsorted, massive to crudely stratified sedimentary unit composed of varying amounts of silt, clay, sand and gravel, and outwash is defined as a well sorted stratigraphic unit consisting of primarily sand and gravel with little or no silt and clay.

The lower till unit observed during drilling activities was encountered at approximately elevation 700 ft MSL (approximately 200 to 220 ft below ground surface; wells MW1C, MW2C, W5DD and W39D on cross-sections A-A' and D-D' on Drawings 12686-15 and 17). This lower till unit lies unconformably over the Coldwater Shale, and is assumed to be deposited in early Woodfordian time. This unit does not appear to be present throughout the area. It was not encountered at comparable depths at wells W2DR, W32D, W40D or W41D. The lower till unit is overlain by outwash deposits.

During analysis of boring logs, three different types of outwash (facies) were recognized. These facies represent deposition of outwash from a melting glacier in different hydraulic regimes. The facies identified include:

- proximal outwash (coarse sand and gravel deposited in a high energy environment near a melting glacier);
- medial outwash (fine to medium sand and silt deposited in intermediate energy environments); and
- distal outwash (silt, clay and silty clay deposited in a low energy environment typically at larger distances from the glacier).

Outwash thicknesses encountered between the deep and the intermediate till units varied from between 52 ft at well location MW2C to 145 ft at well W5DD. The predominant facies in this sequence consist of proximal, coarse grained outwash, with distal fine grained silt and clay outwash deposits varying from 0 ft thick at well MW1C to 33 ft thick at well W5DD (Table 5-1).

The intermediate depth till unit was encountered between approximate elevations 750 ft and 850 ft MSL at most wells drilled to this depth. The intermediate till unit was observed to be thickest at well W41D (90 ft) and non-existent at wells W2DR, W5DD, W27D, W28D, W32D or municipal well PW4. Several intervening sequences of outwash deposits were encountered within this till at monitoring well MW2C, and industrial well R2. The majority of this till consists of clay or silt, with a sandier till encountered at wells W7D, W8D and City test well TW84A. Textural variations such as these typically reflect different ice lobe depositions within an area, with the Lake Michigan Lobe and Erie Lobe depositing silt and clay till, and the Saginaw Lobe depositing the sandier till (Table 5-1). The variations in thickness and soil type of this intermediate till is best shown in cross-section D-D' (Drawing 12686-17). The till is shown to be present at wells W39D and W5D on opposite sides of an area where the till is not present. The till may not be present in this area either because the till was never deposited or a subsequent drainage-way eroded the till.

Outwash thickness encountered between the intermediate till unit and the near surface till unit (where present) consisted of sand and silty sand, and varied in thickness from 20 ft at well W5DD to 100 ft or more at wells W11D, W34I, W36D, and W40D. Distal (finer grained) outwash facies within this unit were mostly thin or absent.

A surficial or upper till unit was encountered above the previous outwash sequence except at well locations R2, W11D, W30D, and W32D. The upper till unit, where present, has a relatively uniform thickness which varies between less than 5 ft at well W2DR to 15 ft at well MW1C (Table 5-1) except near well W6D where the upper till unit is approximately 51 ft thick. However, this unit is fairly uniformly 10 ft thick. This unit is capped by thin sandy topsoil at most locations, or locally capped by man-made fill.

### 5.3 LOCAL HYDROGEOLOGY

#### 5.3.1 Hydrostratigraphy

For functional simplicity, glacial soils underlying the Site were divided into two categories. Sequences of glacial outwash deposits or sandy till deposits were considered to be high permeability units, while silty and/or clayey till units were considered to be low permeability units. This rationale provided the basis for determining the hydrostratigraphic relationships underlying the Site.

Using this rationale, an understanding of the interrelationships of the multi-aquifer system underlying the Site can be determined. The Site consists of three sand and gravel aquifers consisting of outwash and sandy till, separated by discontinuous low permeability till units. These are identified in this discussion as the upper, middle, and lower aquifers, and upper, intermediate, and deep till, respectively. These units are graphically shown on cross sections A-A' through F-F' (Drawings 12686-15 through 12686-19). The till units locally act as confining layers for the aquifers. The early Woodfordian or Pre-Woodfordian till, as described in Section 5.1 of this report, in combination and in contact with the Coldwater Shale, is the deep till unit located at the bottom of the multi-aquifer system. The municipal wells (PW2, PW3, PW4, and PW5) and industrial wells (F1, R1, R2, R3, R4, and R5) pump from the lower aquifer, directly above the Woodfordian till/Coldwater Shale boundary. Pumping rates for these wells are shown on Figure 1.

#### 5.3.2 Hydraulic Gradients

Groundwater levels at the Site were measured 15 times during the period December 1987 through November 1989. The measurements have been used to determine vertical and horizontal groundwater hydraulic gradients at the Site, and to determine the direction of

groundwater flow. Table 5-2 shows measured groundwater elevations, and Table 5-3 shows calculated vertical hydraulic gradient measurements obtained at the Site. Appendix B contains the methods used to measure water levels.

At each well nest, there is generally a downward gradient (0.0001 to 0.19 ft/ft), except once at well nest W2S/W2I; twice at well nest W27I/W27D; and three times at well nest W26S/W26I. Vertical gradients at well nests W-2 and W-35 and between wells W26S/W26I and wells W27I/W27D are very small. The presence and thickness of an upper till unit appears to significantly affect vertical groundwater flow. Significant thickness of this upper till unit seems to be related to a relatively high vertical gradient, as seen at well nests W6 and W8 (greater than 0.1 ft/ft). Vertical gradients measured at well nests where the intermediate till unit was encountered typically range from 0.01 to 0.02 ft/ft, except at well nests W27 and W28 where gradients indicate nearly horizontal flow. The intermediate till unit is comparatively thin at well nests W27 and W28, which may indicate proximity to the edge of a confining unit, as shown on Drawings 12686-16 and 12686-18. However, resistance to vertical groundwater flow through the intermediate till unit appears to be lower than that of the upper till unit, based on the magnitude of the vertical gradients shown on Table 5-3.

The magnitude of vertical gradients may also be indicative of the proximity of a well nest to an active pumping well or point of groundwater discharge. For example, large magnitude vertical gradients occur between wells MW1A and MW1B in the vicinity of pumping well R5, and wells in well nests W8 and W29 in the vicinity of pumping well PW5. Similarly, well nests W4S/GW2 and W6 are located near the Sturgis Foundry Corporation cooling water discharge. In the case of wells MW1B, W8D and W29D, heads are depressed due to pumping, while heads in wells W4S and W6S are elevated due to relatively thick sequences of the upper till unit, and proximity to a point of groundwater discharge.

### 5.3.3 Water Table and Potentiometric Surfaces

Drawings 12686-7 through 12686-10 are water table maps which display the relationships of the flow system to low permeability till units and pumping centers. The water table maps show water table conditions which are relatively consistent during this investigation.

The maps show a water table depression centered on the area around well nest W32 and W2. This depression is caused by pumping in the lower aquifers resulting in groundwater moving from the upper aquifer to the lower aquifers through windows in the confining units. The maps also show a groundwater mound occurring in the vicinity of well MW4, likely due in part to surface water discharge to the Sturgis Foundry Corporation absorption pond, and generally high groundwater elevations occurring at locations where considerable thicknesses of the upper till unit are present, as in cross-section C-C' (Drawing 12686-16). Water table depressions occur in the vicinity of the R1 through R5 pumping wells and at well nest W2. The depression around wells R1 through R5 apparently results from a combination of pumping in the lower aquifer with lower resistance to flow between the upper and lower aquifers.

Drawings 12686-11 through 13 are potentiometric surface maps which show the head in the lower aquifer. Pumpage from municipal and industrial wells appears to have reduced the head in the lower aquifer throughout the City and provides the mechanism to produce the downward vertical gradients discussed above. There are no clear temporal trends in the maps. It appears that changes in pumping rates and recharge may cause small scale local changes in the flow system. These drawings also illustrate the relatively flat horizontal gradient present in the lower aquifer. Widespread pumping effects, combined with high hydraulic conductivity in the lower aquifer, likely produce this effect.

#### 5.3.4 In-situ Hydraulic Conductivity Tests

In-situ hydraulic conductivity tests were performed in 39 wells and piezometers at the Site. Results of the hydraulic conductivity tests are shown in Table 5-4. Test methods are contained in Appendix B.

Table 5-5 shows a statistical summary of the in-situ hydraulic conductivity tests. The 80% confidence interval of the conductivity for each permeable unit (upper, middle, and lower outwash deposits) describes the units' variability. The data is log-normally distributed. This log normal distribution was used in making the confidence interval estimates. The confidence intervals show that the distributions of conductivity are nearly identical in the

lower and middle outwash (i.e., it is statistically impossible to distinguish differences in conductivity between these two units). Although the confidence interval in the upper outwash ( $1 \times 10^{-2} < K < 3 \times 10^{-2}$  cm/s) overlaps the confidence interval for the other units ( $1.9 \times 10^{-2} < K < 6 \times 10^{-3}$  cm/s for the middle outwash and  $1.1 \times 10^{-2} < K < 5 \times 10^{-3}$  cm/s for the lower outwash), it appears that the upper outwash is slightly more permeable than the lower outwash deposits.

#### 5.4 SITE ECOLOGICAL CONSIDERATIONS

During the course of the RI/FS, soil samples were collected at the ground surface and were submitted to CLP for chemical analysis. The purpose of surface soil sampling was to quantify risk, in the vicinity of contaminant source areas, to individuals who might come into contact with organic and/or metals contaminants. Section 10 (Risk Assessment) discusses these risks. Section 7 (contaminant characterization) discusses the relative attributes of the contaminant source areas, including contaminant locations, concentrations, fate, transport, and persistence. A formal Site ecological investigation was not performed, due to the industrialized nature of the Site, the absence of potentially sensitive environments (wetlands, flood plains, wildlife breeding areas and refuges, and wild and scenic rivers or parks) in proximity to the Site, and upon concurrence with MDNR.



## **6.0 DATA VALIDATION**

The purpose of this section is to describe the overall technical quality of the chemical analysis data and to provide an assessment of its validity for use in characterizing the Site. Two general categories of analytical procedures were employed during the RI, namely VOC analysis of samples on-location using portable gas chromatographic instrumentation (field GC) and analyses performed through the EPA Contract Laboratory Program (CLP). CLP analytical services included analysis of Target Compound List (TCL) organic chemical constituents, Target Analyte List (TAL) inorganic constituents and selected inorganic constituents to characterize groundwater geochemistry. When the CLP analyses were performed in accordance with standard protocols (i.e., Statement of Work for Organics Analysis and Statement of Work for Inorganics Analysis), they are referred to as routine analytical services (RAS). Special analytical services (SAS) were also utilized for various nonstandard protocols, such as lower detection limits.

Field GC measurements were employed during the RI as a screening tool to identify areas of VOC contamination for subsequent investigative activities, such as well screen placement and determination of soil boring locations. The level of accuracy and precision associated with these methods is less than that of analytical procedures performed through the CLP; however, was sufficient for its intended purpose. Because data generated from field GC methods are considered approximate, a less detailed technical review of these data was performed. Thus, the main focus of the chemical analysis data validation activity is on the data generated through the CLP.

### **6.1 CLP DATA VALIDATION PROCEDURES**

Determination of data usability was accomplished in several steps. First, analytical results were reviewed by the performing laboratory and assigned qualifying symbols (hereafter referred to as qualifiers) for various problems encountered during sample analysis. Data packages received from the laboratory (including raw data and quality control information) were then reviewed by Warzyn's chemists. This review included assessing laboratory performance against criteria that evaluate analytical methods and instrumentation (e.g., holding times and instrument calibration) and also against criteria

that are sample and/or matrix dependent (e.g., duplicate spike analyses, dilutions and interference checks). Sample collection procedures were also addressed in this evaluation. Guidelines established by the U.S. EPA (U.S. EPA, 1985 and 1988) were used as the basis for this data validation.

Data presented in the appendices show data qualifiers assigned by both the performing laboratory and Warzyn data validation staff. Tables 6-1 and 6-2 summarize the definitions of data qualifiers used for organic chemicals and inorganic analytes in this report, respectively. The most frequently used qualifier was "J", indicating that the quantification of the compound is known with less certainty than that of unqualified data. However, the degree of the uncertainty as well as the direction of the bias (under or over estimation) associated with the data is not the same for each estimated value and is often difficult to ascertain for individual samples. Table 6-3 lists examples of conditions in which organic compound analytical results would be qualified as estimated. Estimated data are considered to be of sufficient quality to be used with unqualified data for Site analysis. In some cases, data were considered unusable ("R" qualifier), generally due to difficulties encountered during laboratory analysis. Unusable data do not provide any information about the presence or absence of the particular compound in the sample and were, thus, not utilized for Site characterization. Determination of this information would require reanalysis of the sample.

Samples were evaluated against blanks in accordance with U.S. EPA guidance (U.S. EPA, 1985 and 1988), as described below. The presence of common laboratory chemicals (methylene chloride, acetone, toluene, 2-butanone and common phthalates) at concentrations less than or equal to 10 times the concentration of the method blank were considered to be the result of laboratory contamination. Other compounds found in samples and associated method blanks were evaluated similarly, with the exception that a factor of 5 (instead of 10) was used to distinguish artifactual contamination. In other words, these chemicals were considered to be the result of laboratory or field contamination if their concentrations in samples were less than 5 times that of associated

blanks. Field and trip blanks were used to evaluate sample quality in a manner similar to method blanks. Analytical data considered to be the result of laboratory or field contamination based on the criteria described above were not used for Site analysis.

## **6.2 CLP DATA USABILITY**

The following describes data usability for samples analyzed through the CLP, organized by the following environmental media: groundwater, subsurface soils, surface water and sediment. Because of the large volume of data quality information provided with the CLP analyses, the rationale for each data value qualifier is not provided. The following sections highlight the most significant data quality issues.

### **6.2.1 Groundwater**

Table 3-1 summarizes CLP sample analysis information for groundwater samples collected during Sampling Rounds 1 through 4 and during well drilling activities.

#### **6.2.1.1 Volatile Organic Compounds**

Both SAS and RAS were utilized for VOC analysis of groundwater samples.

Low concentrations of toluene (generally less than 5 ug/L) were detected in groundwater samples collected during all sampling events, analyzed by either SAS and RAS. Similar levels of toluene were also detected in field and trip blanks. This suggests that sample containers were contaminated with low levels of toluene. This was also documented by the field GC, systematically narrowing down the source of toluene to the bottles. Therefore, toluene concentrations detected in investigative samples were qualified "U" (non-detected) if the concentration was less than or equal to 10 times the level in associated blanks, as described above. As a result of this evaluation, all positive toluene results identified in investigative groundwater samples were considered an artifact of sampling, and not a characteristic of groundwater.

Two common laboratory chemicals (acetone and methylene chloride) were detected in method, field and trip blanks. The presence of these compounds in associated investigative samples was assessed for the possibility of sample contamination as described in the previous section and qualified as appropriate.

Various other chemicals were periodically detected in field and trip blanks and include styrene, chloroform, bromodichloromethane, dibromochloromethane, 2-hexanone and 4-methyl-2-pentanone. The presence of these chemicals in blanks is most likely attributable to source water used for the blanks. The detection of these compounds in investigative samples was evaluated as described above.

Two compounds of concern at the Site, tetrachloroethene (PCE) and trichloroethene (TCE), were infrequently detected in field and trip blanks in Rounds 2, 3 and 4. Evaluation of investigative sample data usability in light of these results is described below:

1. Field Blank FB05-02 contained 0.2 ug/L PCE. Investigative samples associated with this blank did not contain detectable levels of PCE. Thus, PCE results for these samples were not qualified.
2. Trip Blank TB05-03 contained 19 ug/L TCE. This finding may indicate cross-contamination from TCE-containing samples included in the same shipment or possible carryover-contamination between samples during laboratory analysis. Samples W2DR-03 and W2DR-93, containing very high levels of TCE (ca. 15,000 ug/L), were contained in the shipment and may be the source of the trip blank contamination. Samples associated with the blank contained greater than 5 times the TCE concentration in TB05-03 and were therefore not qualified, except sample W37I-03 (77 ug/L). The TCE value for this sample was qualified as "U", not detected.
3. Field Blank FB01-04 contained 2.0 ug/L TCE. Investigative samples associated with this blank contained either no detectable levels of TCE or more than 5 times the level of TCE in FB01-04. An exception to this is sample W23S-04, which contained 2.0 ug/L TCE. This value was qualified as "U" not detected. Other associated investigative sample data was not considered limited by the blank contamination.
4. Field Blank FB04-04 contained 910 ug/L TCE. This finding was considered the result of incomplete sampling equipment decontamination following the collection of a sample containing a very high concentration of TCE (W2DR-04, 17,000 ug/L). Because no samples other than FB04-04 were collected after

sample W2DR-04, contaminant carryover was considered isolated to this blank. Further qualification of other associated investigative samples (collected the same day as sample FB04-04) was not considered appropriate.

5. A low level (2.0 ug/L) of TCE was identified in Trip Blank TB04-04. Samples associated with this blank contained TCE levels greater than 5 times the level in TB04-04. Thus, TCE data for these samples were not considered to be limited by the trip blank contamination.

In some data sets, analytical results for a specific compound were determined to be unusable. This was often the case, with both SAS and RAS, for the analysis of 2-butanone (when the compound was not detected in the sample). This is a common problem with CLP services and is related to laboratory difficulties in measuring this compound. Similarly, analytical data for acrolein (Rounds 3 and 4), 2-chloroethylvinylether (Round 4) and 4-methyl-2-pentanone (Round 4) were often considered unusable when these compounds were not detected in samples.

Duplicate analyses of samples collected at well W42S during Round 4 showed very poor agreement for TCE (6,500 ug/L, W42S-04 and 3.0 ug/L, W42S-94). These data were qualified as unusable ("R").

VOC data from the analysis of six samples collected during Round 2 were determined to be unusable as a result of poor laboratory performance (failure to meet internal standard or surrogate recovery criteria). These samples include W4S-02, W6S-02, W8S-02, MW2C-02, FB01-02 and FB03-02. Loss of these samples was not critical to the interpretation of data at these wells because other samples were collected and analyzed during other sampling rounds. Samples W2S-02, W3S-02, W5D-02, W7S-02, W7D-02 and GW2-02, collected during Round 2, were lost by the performing laboratory. In addition, the same performing laboratory qualified some results with an undefined qualifier ("X"). X-qualified data include methylene chloride and chloroform results of sample F1-02, methylene chloride results for sample W2I-02, TCE results for sample MW4-92, and PCE results for sample R2-02. These data were considered unusable. The usability of results for other chemicals analyzed in these samples were not limited by this qualification.

Occasionally, sample results were qualified "E" by the laboratory indicating that the compound exceeded the calibration range of the analytical method. These samples were usually diluted ("D" laboratory qualifier) and reanalyzed. When samples were not diluted and reanalyzed by the laboratory, data for compounds exceeding the calibration range were qualified as estimated ("J").

#### 6.2.1.2 Semivolatile Organic Compounds

Groundwater samples were analyzed for semivolatile organic compounds using RAS. Analytical data show few compounds detected in this analysis category. Also, few data quality problems were encountered for the semivolatile organic compounds.

A common laboratory chemical, bis(2-ethylhexyl)phthalate, was detected in some method blanks. When this compound was present in samples at concentrations less than 10 times the concentration of associated blanks, it was considered a sample artifact, and qualified as being not detected.

The analytical quantitation limits for six polyaromatic hydrocarbons for samples W2DR-03, W26S-03 and W34S-03 were estimated due to failure to meet internal standard criteria. In addition, 3-nitroaniline results were considered unusable for sample W11S-03 due to failure to meet calibration criteria.

#### 6.2.1.3 Pesticides/PCBs

RAS were used to analyze for pesticides and PCBs in groundwater samples. Results of these analyses indicated no detectable levels of parameters measured.

Several problems were identified with these analyses. Analytical data from samples W2DR-03, W19S-03 and W37I-03 were considered unusable because surrogate compound recovery criteria were not met. Sample quantitation limits for sample W34I-03 were considered estimated because recovery of surrogate compounds was low. Finally, analyses for AROCLORs 1221 and 1232 were considered unusable for samples GW7-02, R4-02 and W1S-02 because chromatographic information was not provided by the performing laboratory.

#### 6.2.1.4 Metals

Groundwater samples were analyzed for TAL metals using RAS and for calcium, magnesium, potassium and sodium using SAS.

Few atypical analytical problems were identified for this analysis type. In some cases, data values or qualification limits were considered estimated, due generally to duplicate analyses, spike analyses or ICP serial dilution analyses failing to meet data validation criteria. Thallium analyses from Round 4 groundwater samples were often qualified as unusable when thallium was not detected in the sample because of low digestion spike recovery. In addition, sodium analyses (SAS) of Round 3 groundwater samples were periodically considered unusable resulting from failure to meet spike recovery criteria.

#### 6.2.1.5 Indicator Parameters

Indicator parameters refer to a set of inorganic analyses (e.g., alkalinity, chloride, sulfate) used to characterize groundwater geochemistry. A list of the indicator parameters is found in analytical data summary tables in Appendix E-7. The indicator parameters were analyzed by SAS. When data was considered estimated (detected values and quantification limits), it was generally due to either holding time exceedances or failure to meet other QC criteria. Total organic carbon results from samples collected during Round 3 were considered unusable, because the QC information provided by the performing laboratory was incomplete.

#### 6.2.2 Soils

Table 3-3 summarizes CLP sample analysis information for samples collected from soil boring locations and collected during well installation activities.

A common and frequent problem associated with subsurface soil analysis, was occasional poor duplicate sample results. This result was attributed to the presence of stones in some samples leading to non-homogeneous matrices among duplicate samples. Because of this fact, comparing results of duplicate soil samples is not a primary criterion for assessing data quality for soils.

#### 6.2.2.1 Volatile Organic Chemicals

Both SAS and RAS were utilized for VOC analysis of subsurface soil samples. Few atypical data quality problems were identified.

Some investigative samples and associated method blanks analyzed by both SAS and RAS contained common laboratory chemicals (acetone and methylene chloride). The presence of these compounds was evaluated for possible laboratory contamination as described previously. Data for 2-butanone analyses from both SAS and RAS were generally considered unusable when the compound was not detected (considered estimated "J" when detected). This common problem is related to laboratory difficulty in analysis for this compound.

#### 6.2.2.2 Semivolatile Organic Chemicals

Semivolatile organic chemicals were analyzed using RAS. This analysis category showed few data quality problems. Common laboratory contaminants (e.g., phthalates) were detected in some laboratory method blanks. The presence of these compounds in associated samples was evaluated as described in a previous section. Compounds detected were frequently qualified as estimated "J" by the laboratory. This action was taken because the measured concentrations were below the contract-required quantitation limit for the analysis.

#### 6.2.2.3 Pesticides/PCBs

Subsurface soil samples were analyzed for pesticides/PCBs using RAS. Compounds of this analysis category were not detected in any sample with the exception of AROCLOR 1260 in Sample SB19-04. Few problems were identified with the analysis of these samples. The quantitation limits for some samples were estimated because the sample extraction occurred beyond the holding time QC criterion.

#### 6.2.2.4 Metals

TAL metals were analyzed in subsurface soil samples using RAS. The results of thallium analyses for many samples were considered unusable "R" as a result of poor post digestion spike recovery. Data were most often qualified as estimated as a result of low



spike recovery. In addition, poor duplicate analyses was a common and frequent problem encountered in this analysis group. This was attributed to non-homogeneous samples resulting from the presence of stones in some samples.

### 6.2.3 Surface Water and Sediment Samples

Surface water and sediment samples were collected from four locations and analyzed for VOCs using SAS. These locations include gravel pits used as storm runoff or effluent discharge points at Ross Laboratories, Kirsch Co. Plant No. 2, and the Sturgis Foundry Corporation. Drawing 12686-5 illustrates the sample collection points.

VOCs were not detected in the surface water samples with the exception of TCE in the sample from location 4. Methylene chloride, a common laboratory contaminant, was identified in the laboratory method blanks for VOC analysis of the sediment samples. The levels of methylene chloride in these samples generally exceeded the criterion for classification as a laboratory contaminant, but were considered estimated. The analytical results for 2-butanone were considered not usable due to laboratory analytical difficulties.

## 6.3 FIELD GC ANALYSES

Field GC analyses were used to estimate VOC concentrations onsite for the screening of source locations and determination of soil boring and well screen locations. While the primary purpose of the GC analyses was to provide an estimate of concentrations and a comparison of relative levels of constituents from one sample to the next, results were quantifiable. QC procedures, however, were limited to calibration checks and duplicate analyses. Three types of samples were analyzed by field GC and include groundwater headspace, soil headspace and soil gas. Data from these analyses are presented in Tables 6-4, 6-5 and 3-3. To assess the general quality of the field GC measurements, data from samples analyzed by both field GC and CLP procedures were compared.

### 6.3.1 Groundwater Headspace

The results of groundwater headspace analyses (Table 6-4) were generally in good agreement with results of groundwater sample analyses performed through the CLP (Appendix E). Agreement between analytical methods appeared best when chemical

concentrations ranged from approximately 10 to 1,000 ug/L. Compounds identified at low concentrations (< 10 ug/L) were often detected by one method, but not the other, and may be related to differences in method quantitation limits. Compounds present at high concentrations (approximately greater than 1,000 ug/L) were identified by both methods, however, were not in close agreement with respect to specific concentration levels (differed by a factor of 2 to 3). As with samples analyzed through CLP, investigative samples and blanks analyzed by field GC often contained toluene, which was attributed to sample container contamination. Field GC analyses also identified benzene as a sampling artifact.

#### 6.3.2 Soil Headspace

Results of field GC analysis of soil headspace (Table 6-5) were, qualitatively, in general agreement with results of the CLP analyses of soil borings (i.e., compounds detected at concentrations greater than approximately 30 ug/kg were generally identified by both methods). Results obtained from CLP analyses tended to be lower than field GC measurements. However, the concentrations of chemical constituents identified by the two methods differed by an inconsistent factor. Low concentrations of toluene and benzene were identified in investigative samples and blanks and were attributed to contaminated sample containers.

#### 6.3.3 Soil Gas

Field GC analyses of soil gas are presented in Table 3-2. Based on comparison of field GC methods and CLP methods for groundwater and soil headspace analyses, soil gas measurement are considered acceptable. Toluene was identified in many investigative samples and was considered an artifact of the analysis.

#### 6.4 SUMMARY

The usability of chemical analysis data performed through CLP is considered acceptable for Site characterization for both unqualified values and values qualified as estimated. In general, the performance of most analytical laboratories was satisfactory. Common organic laboratory chemicals detected in some investigative samples and associated blanks were considered the result of laboratory contamination (e.g., acetone, methylene chloride, phthalate compounds). Toluene was commonly identified in VOC analyses of

groundwater and soil. This finding was generally considered to be the result of toluene present in sample containers. In addition, 2-butanone analyses were generally unusable, resulting from typical laboratory problems.

A comparison of the results of duplicate analyses by RAS and SAS showed agreement with respect to identification of specific compounds. Data obtained through RAS, however, generally appeared several times lower than data obtained through SAS, based on a comparison of chlorinated ethene compounds in groundwater samples. Occasional field and trip blanks contained TCE and PCE, compounds of concern at the site. Evaluation of this information resulted in limiting the usability of only a small number of samples.

Analysis of groundwater and soil samples for inorganic constituents was associated with few atypical problems. Periodic poor agreement among inorganics results for duplicate samples was attributed to the non-homogeneity of soil samples.

Results of VOC analyses measured by field GC were in general agreement with corresponding CLP analyses. These results were considered acceptable as a semi-quantitative screening tool in the RI.

## **7.0 CONTAMINANT CHARACTERIZATION**

### **7.1 SOURCE AREA CHARACTERIZATION**

Source area characterization provides information on the contaminant concentrations at the areas where disposal may have occurred. Because the primary contaminants (PCE and TCE) are more dense than water in their pure form, a key goal of the source area investigation is to determine if these contaminants are present as non-aqueous phase liquids (NAPLs). If NAPLs are present, they will serve as a continuing source of contamination as they slowly dissolve.

The high levels of contamination found deep in the aquifer might suggest the introduction of chlorinated ethenes into the aquifer was in the form of a dense nonaqueous phase liquid (DNAPL). The DNAPL would have moved downward through the aquifer and along the upper surface of the aquitard under the influence of gravity. However, the RI did not find evidence of a DNAPL during the groundwater or soil sampling investigation tasks, and the groundwater flow model (see Section 9.0 for details) shows the hydraulic gradient is sufficient to move contaminants vertically. TCE has a solubility of 1,100,000 ug/L. The maximum TCE concentration identified in groundwater was 20,000 ug/L, from samples collected during the boring of wells W26D and W34I. Since these observed concentrations are approximately 2% of the solubility limit, it is unlikely that DNAPLs are present in the groundwater.

An important source of continuing contamination from the unsaturated and saturated soils is residual saturation. After the DNAPL has moved through the permeable deposits, a small amount of the DNAPL remains as a coating on a soil grain, slowly dissolves, and results in a continuing source of contamination.

If encountered by a boring or well, saturation by DNAPLs is relatively easy to determine based on the VOC results. Under DNAPL saturated conditions, voids between soil grains will be full of the solvent, and soil and groundwater concentrations would be in the percent range, with the concentration in soil generally far exceeding the VOC's solubility limit in water. Residual saturation is more difficult to identify, because of the variable amounts of solvent which may remain or, in the case of soil samples from above the water

table, the variable water content of a soil horizon due to fluctuations in both the water table and capillary fringe. When the contaminant concentrations approach the aqueous solubility limits of 1,100,000 ug/L for TCE and 150,000 ug/L for PCE, DNAPL is present. Assuming a soil water content of 1%, a soil porosity of 0.3 and solid density of 2.65 g/cm<sup>3</sup>, the maximum mass of dissolved TCE in a liter of soil is  $0.01 \times 0.3 \times 1,100,000$ , or 3,300 ug, the mass of soil in a liter is  $0.7 \times 2.65 \times 1000$  g/kg, or 1.855 kg, and the resulting soil concentration is  $3300/1.85$ , or 1780 ug/kg. The maximum mass of dissolved PCE in a liter of soil is  $0.01 \times 0.3 \times 150,000$ , or 450 mg, and the resulting soil concentration is 240 ug/kg. Due to the strong dependence on water content, these soil concentrations should be used as an order of magnitude indicator of residual saturation. A summary of CLP soil analyses is presented in Table 7-1.

#### 7.1.1 Kirsch Co. Plant No. 1

Contamination at the Kirsch Co. Plant No. 1 was characterized by soil gas, soil, and groundwater sampling. The soil gas sampling was used as a screening tool to select soil or groundwater sampling locations.

##### 7.1.1.1 Organic Concentrations

The soil gas survey for Kirsch Co. Plant No. 1 was conducted in three rounds: September 1987, June 1988, and July 1988. Thirty-five samples were collected from Kirsch Co. Plant No. 1. Table 3-2 contains the VOC concentrations observed at the sampling locations. VOCs were detected in 21 of the 35 samples. The primary contaminants observed were TCE, PCE, 1,2-DCE, and 1,1,1-trichloroethane (TCA). Toluene was also detected, but was attributed to contaminated sample containers. The highest concentration of VOCs detected in Phase II soil gas was found at location SG2-115, in the southwest corner of a lot owned by Kirsch Co., adjacent to Kirsch Co. Plant No. 1 (1195 ug/L TCE; BMDL PCE). Other noticeably high concentrations of TCE and/or PCE were detected in samples collected in the vicinity of SG2-115, and in the City right-of-way south of this area. Soil gas samples collected along the City right-of-way of E. Main Street, north of the Kirsch property, contained TCA and 1,1-dichloroethene (DCE) in concentrations of

total VOCs of BMDL to 3.4 ug/L. VOCs were not detected in soil gas samples collected in City right-of-ways along Susan Ct. and Lakeview Avenue, east and northeast of the Kirsch property, and N. Prospect Street, north of E. Main Street.

Headspace analysis of the soils collected from shallow borings (Table 6-6) was performed to show the distribution of VOCs in the unsaturated zone (Drawing 70084-B8). Soil borings SB-01R through SB-08 and SB-18 through SB-21 were performed on the Kirsch's vacant lot north of the building, northeast of the corner of N. Prospect and E. Main Streets. Each of the 47 soil samples collected for headspace analysis from these borings contained quantifiable concentrations of VOCs, except two samples (SB-01R at 2.5 ft, and SB-05 at 5 ft) which had results at below method detection limit (BMDL).

Soils from well drilling at locations W20, W22, W23, W24, and W26, contained detectable levels of VOCs by field GC methods (W20 ranged from BMDL to 25.6 ug/kg, W22 ranged from 4.0 to 17.9 ug/kg, W23 ranged from 35.4 to 6130, W24 ranged from 26.6 to 167 ug/kg, and W26 ranged from BMDL to 154 ug/kg). Soils from well W21S, located along the eastern property boundary, did not contain detectable VOC concentrations according to field GC methods. The highest concentrations were observed in soil boring SB-06 (well nest W34) and decrease from 173,000 ug/kg at a depth of 2.5 ft to <1,000 ug/kg at depths greater than 7 ft.

Of the 39 CLP samples taken from SB-01, SB-02, SB-06, SB-07, W11S, W26S, and W42S, 28 samples had quantifiable levels of TCE (SB-01 ranged from 10 to 150 ug/kg, SB-02 ranged from ND to 6 ug/kg, SB-06 ranged from 100 to 27000 ug/kg, SB-07 ranged from 4 to 160 ug/kg, W11S ranged from 4 to 8,200 ug/kg, W26S ranged from ND to 4 ug/kg, and W42S ranged from 61 to 99,000 ug/kg). The maximum CLP concentration was observed at W42S at a depth of 2.5 ft (99,000 ug/kg TCE and 18,000 ug/kg PCE) (Drawings 70084-B11 and B12).

CLP data (Appendix F-3 and F-7) as condensed in Table 7-2 for samples from SB-06, W11S, and W42S also show the same distribution of TCE and PCE in the shallow soils. This decrease suggests that the remaining contamination is held in the shallow soil either

through adsorption to organic matter or residual saturation. This contamination will continue to be slowly released to the aquifer as infiltration moves through the shallow contaminated soil.

Table 7-2 also shows that the composition of VOC contamination in the soils varies across the property. For example, at location SB-06, 97.2% of the contamination in the 2.5-ft depth sample is from TCE, while at W11S, 96.9% of the contamination in the 1-ft depth sample is from PCE. Two VOCs were detected in surface soils (0.5 ft) at very low concentrations. 1,1,1-trichloroethane (2 to 4 ug/kg) was detected in four of eight samples and TCE (2 ug/kg) was detected in three of the eight samples collected.

During drilling, 29 groundwater samples were collected and analyzed, using field GC headspace methods, to determine the presence and extent of VOCs in the aquifer near Kirsch Co. Plant No. 1 (Table 6-4) at wells W11S, W11D, W20S, W21S, W22S, W23S, W24S, W25S, W26S, W26D, W34S, and W34I. Twenty-five of the samples had detectable VOC concentrations. Of the ten CLP samples submitted from wells W11D, W26S, W26D, W34I, and W34S, nine samples had detectable levels of VOCs (Drawing 70084-B26). TCE and PCE were the prevalent VOCs detected in the groundwater samples. The highest CLP total VOC levels were found at wells W26S (16,078 ug/L) and W34S (8,970 ug/L). A number of samples were collected during the construction of W11D, W26S, W26D, W34S, and W34I to provide a vertical profile of contamination in the aquifer. At each of these locations, the highest VOC levels were found at the water table (see vertical profile on Drawing 12686-20). Drawing 12686-20 shows that concentrations near the Kirsch Co. Plant No. 1 are highest near the water table and decrease with depth into the aquifer (e.g., at well nest W26, the water table concentration is 16,000 ug/l ethenes and the deepest piezometer, W26D, has a concentration of 3 ug/l). Four rounds of CLP sampling were conducted for this investigation (Appendices E-2, E-4, E-5 and E-9). VOC concentrations at wells W23S and W34S decreased from over 5,000 ug/L during the Round 3 groundwater sampling to no detection (ND) during Round 4 sampling. This decrease may be due to reconstruction of wells W23S and W34S between sampling Rounds 3 and 4.

Not all of the groundwater samples collected from wells in the source area showed decreasing VOC concentrations. VOCs at well W11S consistently rose from 3 ug/L to 150 ug/L over three sampling rounds (Rounds 2, 3, and 4). Given the conflicting changes in the source area well concentrations, insufficient data is available to clearly identify trends in VOC concentration.

The soil and groundwater analytical results suggest a major source of VOC contamination in the vicinity of well nest W34, based on:

- high concentrations of VOCs in shallow soils;
- the presence of VOCs throughout the unsaturated zone soils;
- the lack of high VOC groundwater concentrations upgradient of well W34S (each is less than 36 ug/L);
- the presence of high VOC concentrations in groundwater at downgradient locations (W26, W35 and W2);
- the decrease in VOC concentrations in groundwater with depth in the upper aquifer; and
- the low VOC concentrations in the deeper aquifer (3 ug/l at W26D).

Soil contamination detected downgradient and in the vicinity of W34S may be due to vapor transport from the VOCs present in the unsaturated zone soils or from volatilization from the VOCs in the groundwater.

Although the exact methods (e.g., surface spills, drywell disposal, etc.) of VOC discharge have not been determined, some of the contamination appears to be due to a near surface contaminant release. CLP results from SB-02, SB-06, and SB-07 (Appendices F-3, and F-6) had higher VOC concentrations near the ground surface than the immediately deeper samples. This indicates a near-surface source of contamination in these areas. Two VOCs, 1,1,1-trichloroethane and TCE, were also consistently identified at low concentrations (maximum 4 ug/kg) in surface soils.



Wells (W26S and W2DR) downgradient of this source have higher levels of chlorinated ethene contamination. This indicates that the contaminant mass may have occurred between well nests W26 and W34, or has migrated from the source area.

Polyaromatic hydrocarbons (PAHs; refer to Table 7-1 to determine specific chemicals classified as PAHs) were identified in soils from several boring locations generally at and near the surface. These locations include SB18 at 2 ft, W42S at 2.5 ft, and SB21 at 2 and 4 ft, and all surface soil sampling locations (Drawing 70084-B14). Samples from boring SB19 contained PAHs and Arochlor 1260 (PCB) at only 4 ft and not at 2 and 6 ft in depth. Concentrations for individual PAHs of these locations were generally less than 500 ug/kg. Higher PAH levels were identified at boring SB21 in the sample collected at 2 ft below surface (individual PAHs ranged from 150 to 8100 ug/kg).

One soil sample collected from boring locations at a depth of 2.5 ft contained low concentrations (6 ug/kg or less) of benzene, ethylbenzene, and xylenes. These compounds were not identified at lower depths (5, 7.5, 10, and 15 ft).

Other compounds detected in samples from the Kirsch Co. source area were attributable to sample contamination. The compounds include acetone, methylene chloride, and toluene.

#### 7.1.1.2 Inorganic Concentrations

Unlike most TCL organic compounds, most inorganic constituents analyzed are present in soils and groundwater at detectable concentrations. To distinguish between concentrations of these constituents which may be the results of a chemical release to the environment and concentrations which may be naturally occurring, analytical data were compared to data from background samples. Table 7-3 summarizes the background concentrations of metals for Site soils and groundwater used in this comparison. Samples from wells W11S and PW6 were considered representative of background conditions for inorganic groundwater quality. Samples from locations SB15, SB16, SB17, SB29 and SB31 were used to characterize background levels of inorganic constituents in soil.

Groundwater collected from well W23S contained approximately 18 ug/L of chromium. This concentration exceeds naturally occurring levels of chromium at the Site which are less than 7.8 ug/L. The chromium concentration in soil boring SB02 at the 2.5-ft depth was 62.8 and is also greater than Site background concentrations which ranged up to 20 ug/kg.

Concentrations of cyanide in groundwater and soil at the Kirsch Co. Plant No. 1 property also exceeded background levels. Groundwater samples from well W23S and well W34S contained cyanide at concentrations of approximately 30 ug/L and 284 ug/L, respectively. This may be compared to a background concentration of less than 10 ug/L. Cyanide levels in excess of background were also identified in soil samples at 2-, 4-, and 6-ft depths from location SB19 and at 2 ft from location SB21. These concentrations ranged from 2.0 to 188 mg/kg and may be compared to a background level of less than 0.5 mg/kg.

The concentrations of several other metals were elevated above the concentrations in background samples at several locations. Copper concentrations at locations SB01, SB02, SB18, SB19, SB20, SB24, SB25, SB26 and SB30, representing depths from 0.5 to 6 ft, ranged from approximately 62 to 2,030 mg/kg. This is compared to a background copper concentration of approximately 38 mg/kg. Zinc also appeared to be elevated above background levels in Kirsch Co. Plant No. 1 soils. Zinc concentrations in soils for locations SB01, SB18, SB19, SB20, SB21, SB23, SB25, and SB30, from depths of 0.5 to 6 ft ranged from approximately 125 to 2,010 mg/kg. Background zinc levels were estimated to be approximately 100 mg/kg.

Concentrations of several other metals were present above estimated background concentrations (generally less than 2 times background) in only a few samples. These include, barium, arsenic, cadmium, cobalt, lead, and nickel. Because these metals were not frequently or substantially elevated above background, they are not necessarily the result of a chemical release.

#### 7.1.2 Wade Electric

The Wade Electric property is currently occupied by the Sturgis Archery Center. Wade Electric closed in 1966 and remained vacant until the building burned down in about 1974. The property was purchased by Sturgis Archery Center, and six underground tanks

were removed from the rear of the property. The tanks contained small amounts of a thick oily substance and were not leaking, as reported by the property owner.

#### 7.1.2.1 Organic Concentrations

Contamination at Wade Electric was characterized by soil gas, soil, and groundwater sampling. The soil gas sampling was used as a screening tool to locate soil and groundwater quality sampling. Soil gas results for this property (Table 3-2) ranged from ND to 35 ug/l for TCE, and from ND to 39.8 ug/l for PCE. The soil gas contamination was limited to an area on the southeastern portion of the property in the vicinity of the former underground tanks, near well nest W1.

Soil borings W18S, W33S, and SB09 through SB13 were performed at Wade Electric (Drawing 70084-B9). Thirty-nine of the 49 soil samples collected at Wade Electric (Table 6-6) contained detectable VOCs from field GC methods (W18S ranged from BMDL to 10.3 ug/kg, W33S ranged from BMDL to 7.4 ug/kg, SB09 ranged from 3.06 to 43.2, SB10 ranged from BMDL to 100 ug/kg, SB11 ranged from 20.8 to 126 ug/kg, SB12 ranged from BMDL to 8.67 ug/kg, and SB13 ranged from BMDL to 183 ug/kg).

Of the 38 CLP samples collected from borings SB09, SB10, SB11, SB12, and well W33 (Appendices F-3 and F-6), 13 samples had quantifiable levels of TCE (Drawing 70084-B15). Most of the VOC contamination was found in borings SB10 and SB11. The highest concentration of CLP VOCs was present at boring SB11 at a depth of 4.5 ft (160 ug/kg TCE; 630 ug/kg PCE - Drawing 70084-B16). Boring SB11 was drilled adjacent to the former underground storage tank location. VOCs were also detected in surface soils. 1,1,1-Trichloroethane (maximum 2.0 mg/kg) was identified in each of four samples collected. Chloroform (10 ug/kg) and PCE (6.0 ug/kg) were less frequently detected.

The vertical distribution of contamination in the soils adjacent to the former underground storage tanks show relatively uniform low level contamination (Table 7-4). Because the concentrations are well below the levels identified for residual saturation, it

appears that either the bulk of the contamination may have already moved into the aquifer, leaving only residual concentrations in the soil, or that the source was a water solution containing VOCs.

Twenty-four groundwater samples were collected and analyzed using field GC methods during the installation of W17S, W18I, W19S, and W33S (Drawing 12686-5). Nineteen of the samples had quantifiable VOC levels (W17S ranged from 8.4 to 12.3 ug/L, W18I ranged from BMDL to 10.3 ug/L, W19S ranged from 14.3 to 159 ug/L, and W33S ranged from BMDL to 4.74 ug/L).

The CLP VOC concentrations in groundwater at the Wade Electric facility (Drawing 70084-27) was detected during Phase 1 drilling at well location W1 (Table 6-5) (281 ug/L TCE and 2.19 ug/L PCE at the water table). Phase II wells W17S, W18I, W19S, and W33S were installed at Wade Electric to delineate the position of the contaminant plume at this location. Maximum CLP results from W17S (52 ug/L TCE), W18I (210 ug/L TCE), W19S (330 ug/L TCE), and W33S (160 ug/L) (Appendices E-4 and E-9) indicate the TCE plume occurs in the southeast portion of the old plant area.

In addition to the chlorinated ethenes described above, several other compounds were identified in soil samples from the Wade Electric source area. Chloromethane, chloroform, and chlorobenzene were periodically detected in soil samples collected from locations SB11, SB12, and W33S. The concentrations of these compounds were generally less than 10 ug/kg. The maximum concentration of these compounds at these wells was 6 ug/kg chloroform at SB11, 9 ug/kg chlorobenzene at SB12, and 42 ug/kg chloroform at W33S. PAHs were also detected at these boring locations and in surface soils and ranged from approximately 50 to 1000 ug/kg for individual constituents of the PAH class (Drawing 70084-B12).

#### 7.1.2.2 Inorganic Concentrations

Estimated background concentrations of metals for Site groundwater and soil are presented in Table 7-3. A soil sample from W33S at 1.5 ft in depth contained lead at a concentration (167 mg/kg) which exceeds the background level (approximately 35 mg/kg). This concentration, however, is within a typical range for an urban area. Inorganic

groundwater quality at well GW7 differ from background water quality. Zinc (17800 ug/L) and possibly barium (139 ug/L), and aluminum (83 ug/L) are elevated above background at this location. However, this well was constructed with galvanized steel casing which would explain the zinc concentrations, and possibly the other metals.

#### 7.1.3 Telemark Business Forms

Telemark Business Forms has been at its current location since January 1980. The industrial survey noted that the company uses PCE occasionally in a printing process. The survey also noted that a cleaner containing halogenated solvents (35% PCE and 15% methylene chloride) is used.

##### 7.1.3.1 Organic Concentrations

Contamination at Telemark Business Forms was identified by the soil gas survey and characterized by soil and groundwater sampling. The soil gas sampling was used as a screening tool to locate soil or groundwater sampling. Soil gas results (Table 3-2) for this property ranged from ND to BMDL for TCE and from ND to 10.7 ug/l for PCE (Drawing 70084-B10). The soil gas contamination was limited to an area on the western side of the Telemark building.

Field GC analysis of soil samples was used to further screen samples for CLP analysis. the distribution of contamination shown in Drawing 70084-B10 shows that contamination is primarily limited to the immediate vicinity of well W10S. A small amount of contamination is detected near the water table at well W16S.

CLP soil samples (Appendices F-3 and F-6) collected during the installation of well W10S show relatively high concentrations of PCE (Drawing 70084-B18) at the ground surface (ND TCE, and 110 ug/kg PCE for the 0 to 1 ft sample). The vertical distribution of PCE (Table 7-5) is relatively independent of depth. This indicates that PCE has moved from the surface to the water table and that there probably is not an on-going strong source of PCE.

In addition to chlorinated ethenes, several other organic compounds were detected which may be considered minor contaminants. Soil samples from boring SB15 contained benzoic acid (27 ug/kg), 1,2,4-trichlorobenzene (25 ug/kg), chlorobenzene (up to 9 ug/kg), and bis(2-ethylhexyl)phthalate (350 to 700 ug/kg). In addition, samples from locations SB16 and SB17 contained chlorobenzene at concentrations up to 19 ug/kg.

CLP analysis of groundwater samples (Drawing 70084-B28, and Appendices E-4 and E-9) shows that the PCE contamination appears to be relatively localized (Drawing 70084-B28) while the TCE contamination appears more widespread from an unknown source. Well W10S had a maximum of 11 ug/L TCE and 14 ug/L PCE. Wells W3SR, W31S, and W41S (upgradient and screened in the shallow outwash unit) had no detectable PCE and only 4 ug/L of TCE at W3SR. Wells W31S and W41S did not have detectable levels of TCE or PCE. Well W3SR had 4 ug/L TCE and no detectable levels of PCE. Well W16S, located about 200 ft downgradient from Telemark, contained up to 9 ug/L TCE and no detectable levels of PCE. PAHs were not detected at Telemark (Drawing 70084-B19).

The Telemark facility is not a significant source of contamination to the City's aquifer. Soil contamination near the facility is limited to PCE contamination. The low levels of TCE in the groundwater do not appear to be related to the facility. The extent of PCE contamination in the aquifer is limited to the immediate vicinity of the facility and does not appear to be related to the contamination affecting the Site's water supply wells. Based on the low levels of contamination observed in the soil and groundwater, this facility does not appear to have contributed to the water supply contamination and further investigation of this facility may be conducted under MDNR's Act 307 authority, per discussion with representatives at MDNR.

#### 7.1.3.2 Inorganic Concentrations

Concentrations of inorganic constituents measured in soil or groundwater samples appear similar to background levels.

#### 7.1.4 Sturgis Newport Business Forms

Sturgis Newport Business Forms is a printing company that has been at its current location since 1906. According to plant interviews, a small amount (less than 7 gallons in 3 years) of a solvent containing PCE is used in one area of the plant. The City's sewerage survey report by Sturgis Newport Business Forms states that solvents may have been spilled in the railroad right-of-way adjacent to the rear of the building, although the plant manager maintained that the report was unsubstantiated.

##### 7.1.4.1 Organic Concentrations

Contamination at Sturgis Newport Business Forms was characterized by soil gas, soil, and groundwater sampling. The soil gas sampling (Table 3-2) was used as a screening tool to locate soil or groundwater sampling. Soil gas results for this property ranged from ND to 4.9 ug/l for TCE, and from ND to 103 ug/l for PCE. The soil gas contamination was limited to an area along the east side of the building (the area identified as the probable spill area).

CLP analysis of soil samples (Appendices F-3 and F-6) collected during the installation of well W9S show relatively high concentrations of PCE at the ground surface (ND ug/kg TCE, and 1100 ug/l PCE for the 0 to 1-ft sample). The results of the vertical sampling show that the contamination is limited to the surface soils. Samples collected below 5 ft did not have detectable levels of TCE or PCE.

Groundwater sampling at well W9S (Appendices E-4 and E-9) confirms that the contamination is limited to the surface soils. No detectable levels of VOCs were found in the groundwater at well W9S.

##### 7.1.4.2 Inorganic Concentrations

None of the inorganic compounds measured in soil or groundwater samples collected from W9S appear to exceed background levels.

## 7.2 GENERAL GROUNDWATER CHARACTERIZATION

### 7.2.1 Major Organic Contaminants

The primary contaminants found during the RI of the Site are trichloroethene (TCE) and tetrachloroethene (PCE). Contaminants migrated from source areas to deep within the aquifer under the influence of local groundwater pumping. Drawing 12686-6 shows the areal distribution of chlorinated ethenes in the aquifer. Drawing 12686-6 shows that the strong influence of groundwater withdrawal pulls the contamination to the northwest and possibly to the southwest (although previously uncontaminated, the last round of sampling detected 1 ppb TCE at municipal well PW4).

The vertical extent of contamination is shown in Drawing 12686-20. This drawing is a cross-section which shows a contaminant plume beginning near the Kirsch Company Plant No. 1. The plume proceeds along a curved route to well R4. The contamination moves from the upper outwash unit, through the middle outwash unit, and into the lower outwash unit in a relatively short distance between well nests W26 and W2. This drop in elevation is coincident with the edge of the intermediate till. The high levels of contamination remain in the lower outwash unit until intercepted by well R4. Contaminants present in the past at wells PW1, PW2, and PW3 may also have been due to this source and plume.

### 7.2.2 Minor Organic Constituents

As described above, the primary contaminants identified in groundwater consist of chlorinated ethenes. Compounds of the chlorinated ethane class (1,1,1-trichloroethane, 1,1-dichloroethane, and 1,2-dichloroethane) were less frequently, but consistently, identified in groundwater samples from some locations. The most frequently detected of these, 1,1,1-trichloroethane, ranged in concentration from 0.3 to 9.0 ug/L. A number of additional volatile organic chemicals were infrequently identified in groundwater samples (Table 7-6). Compounds of the trihalomethane class (chloroform, bromodichloromethane, and dibromochloromethane) were identified at low concentrations (2.0 ug/L or less) in wells PW3, PW4, F1, W26S and W27S. Identification of these compounds in municipal wells occurred only in samples collected from Round 3



and may be representative of residual chlorinated water. Chloroform was identified in sampling Rounds 1, 2, and 3 at well MW1A at concentrations ranging from 2 to 16 ug/L.

Acetone was identified at low concentrations (less than 5 ug/L) in five samples collected during Round 3 sampling. Although acetone was not identified in the laboratory method blank associated with these samples, its presence at low concentrations and occurrence in only one sampling round suggest it is the result of laboratory contamination. Low concentrations of benzene (0.2 to 2.0 ug/L) were identified in wells GW4, PW2, and W01S. Because this compound was identified in samples collected from only one sampling round and at low concentrations, its presence may be the result of laboratory or field contamination. Two compounds of the ketone class (2-hexanone and 4-methyl-2-pentanone) were identified at very low concentrations (0.6 and 0.7 ug/L) in groundwater from one location, well GW3. Because these chemicals are commonly found in the laboratory, they may be the result of sample contamination during laboratory analysis.

Several chemicals of the semivolatile organic chemical analysis group were infrequently identified in groundwater samples at low concentrations. These compounds are bis(2-ethylhexyl)phthalate (10 samples, 3 to 51 ug/L), di-n-octylphthalate (4 samples, 2 to 8 ug/L), and benzoic acid (1 sample, 4 ug/L). These results were associated primarily with samples collected during Rounds 3 and 4. Since these compounds are common laboratory and field contaminants, their presence in samples is likely the result of sample contamination. Pesticides or PCBs were not detected in groundwater samples.

### 7.2.3 Inorganic Constituents Identified in Groundwater

#### 7.2.3.1 Target Analyte List Metals

Groundwater samples from selected locations at potential source areas and from municipal water supply wells were analyzed for Target Analyte List (TAL) metals and cyanide (Table 3-1) to evaluate the inorganic quality of the groundwater in these areas. Results of these analyses are contained in Appendices E-3 and E-8. In Table 7-6, the minimum, maximum, and mean concentrations of the inorganic constituents for samples with detectable concentration levels are presented.

Most of the metal parameters included on the TAL occur naturally in groundwater at varying levels. These metals have been categorized, based on typical concentrations commonly encountered in groundwater, into major (1.0 to 1,000 mg/L), secondary (0.01 to 10.0 mg/L), minor (0.001 to 0.1 mg/L), and trace (less than 0.0001 mg/L) constituent groupings (Davis and DeWiest, 1966). This classification is presented in Table 7-7. To determine if specific metals in Site groundwater were present in excess of expected natural concentrations, the sample results were compared to results considered to represent background conditions (wells W11S and PW6). The range of background metals concentrations in groundwater is presented in Table 7-3.

Background groundwater concentrations of barium range from approximately 30 to 75 ug/L. The concentrations of barium in groundwater from well W42S was 176 and 181 ug/L for samples collected during Rounds 3 and 4, respectively. Although well below the EPA Primary Drinking Water Standard of 1,000 ug/L, these values may be elevated in comparison to naturally occurring values.

The concentration of chromium in groundwater samples collected from wells W10S and W23S were 19 and 18.4 ug/L, respectively. Although below the EPA Primary Drinking Water Standard of 50 ug/L, these values may be above the background chromium levels for the Site, which are less than approximately 8 ug/L. Well W23S is reportedly in the vicinity of a former cyanide/metal plating facility located at Kirsch Co. Plant No. 1.

Iron concentrations exceeded the naturally occurring levels and the EPA Secondary Drinking Water Standard of 300 ug/L in well W41D (1,970 ug/L) and possibly in well PW4 (200 to 324 ug/L). The maximum iron concentration detected in groundwater was 87 ug/L. Well W41D also contained higher levels of manganese (462 ug/L) than what is typical of background water quality (ranged from 7.8 to 13 ug/L). Variations in iron and manganese are expected in sand and gravel outwash due to the presence of small areas with high concentrations of these metals in the sand.

The concentration of lead measured in groundwater was 15.3 ug/L in well R1, and 6.4 ug/L in well GW7. These are the only two samples which exceeded the maximum concentration of lead detected in background samples (1.7 ug/L).

Naturally occurring nickel concentrations in Site groundwater is less than an analytical detection limit of approximately 8 ug/L. Nickel concentrations exceeded this level at wells F1 (18 ug/L), PW4 (approximately 20 ug/L), and PW5 (40 ug/L). The higher nickel concentrations in the municipal wells were identified only in samples collected during Round 3 and not from samples collected during Rounds 2 and 4.

The background concentrations of zinc in Site groundwater represented a large range of values (from less than approximately 10 to 1,590 ug/L). A sample collected from well GW7 exceeds this range (17,800 ug zinc/L). Well GW7, installed by the City prior to the RI, is a galvanized steel well. High zinc concentrations are common in wells of this type of construction and is due to the galvanized coating applied to the steel.

Groundwater analyses of total cyanide in background samples were less than the 10 ug/L limit of detection. The concentration of cyanide in well W2DR was identified slightly above the detection limit (approximately 12 ug/L). Wells W19S and W23S contained detectable concentrations of cyanide (10.4 to 17.6 and 23.1 to 34.7 ug/L, respectively). Markedly higher concentrations of cyanide were measured from well W34S (174 and 284 ug/L). Wells W19S, W23S and W34S are located on the Kirsch Co. Plant No. 1 property. This property was used for industrial processes since before 1920. Drawings of the former buildings on the property showed a cyanide/metal reprocessing building adjacent to well W23S. Therefore, the presence of cyanide at these wells is probably due to releases from points of use on the property or at the reprocessing building.

Concentrations of other TAL metals are not discussed, because there was no apparent temporal or spatial trend in the data.

#### 7.2.3.2 Geochemistry

Field observations (pH, specific conductance, temperature, color, odor, and turbidity) for the four sampling rounds are summarized in Tables 7-8 through 7-11. The groundwater pH generally ranges from 7.2 to 7.6. No spatial or temporal trends were observed in the data. The aquifer pH is likely controlled (buffered) by carbonate containing minerals (e.g., dolomite) in the aquifer.

Specific conductance data does show some spatial trends. Specific conductance is a measure of the amount of dissolved minerals. These dissolved minerals may be present naturally or may be due to human activities. Naturally occurring dissolved mineral levels are controlled by dissolution of minerals in the parent material and the rate of groundwater movement carrying (flushing) the dissolved minerals away. Deep portions of a sand aquifer influenced by a more regional groundwater flow system would tend to have higher conductivity than shallow portions influenced by a more local groundwater flow system. Human activities will cause elevated conductivity in the shallow portions of the aquifer through the discharge of wastewaters to the groundwater (through impoundments, land disposal systems, and leaking sanitary sewers) and direct surface application of materials (e.g., road salting and fertilizing). A number of shallow groundwater samples (such as samples from GW7, W25S, and W42S) show elevated conductance levels (ranging from 1785 to 2180 umho/cm) which are probably related to human activities (e.g., road salting). Some samples from deeper in the aquifers (such as samples from W5DD and W41D) also have elevated conductance (ranging from 2,050 to 3335 umho/cm) which appears to be due to the slow flushing of the groundwater flow system deep in the aquifer. These indicators and common metals are summarized in Table 7-6. Groundwater hardness (calculated from geometric means of calcium (91.6 mg/L) and magnesium (27.2 mg/L)) is 340 mg/L.

Since waters with a hardness of 120 to 180 mg/L are considered hard (Benefield, 1982), the Site groundwater is very hard.

The hardness present in the groundwater is due to the slow dissolution of carbonate minerals present in the glacial deposits. Dolomite and other carbonate rich minerals were probably transported to the area by continental glaciers as the glaciers eroded dolomitic bedrock northeast of the City.

Precipitation and groundwater discharges (gaining streams and water supply wells) slowly flush dissolved minerals from the aquifer. These minerals are replaced if undissolved minerals (e.g., dolomite and calcite) are still present in the aquifer.

A qualitative measure of the undissolved carbonates can be obtained by comparing the concentrations present in the aquifer to concentrations that would be present if a particular mineral (e.g., dolomite) was at saturation. This comparison was obtained by running the inorganic equilibrium model WATEQF (WATER EQUilibrium - Fortran, Plummer, et al., 1978). This model calculates logarithmic ratios (solubility indices) between the existing concentrations and equilibrium concentrations for various minerals. Indices greater than zero indicate that the water is supersaturated with respect to the particular mineral.

Saturation indices less than zero do not mean that the solid phase of the mineral is not present in the aquifer. Many minerals (notably dolomite) are very slow to dissolve so equilibrium concentrations are seldom observed.

WATEQF was run on select water samples from the aquifer. Results from a representative water supply well, PW4 (Table 7-12), show that the minerals calcite ( $\text{CaCO}_3$ ), dolomite ( $\text{CaMg}(\text{CO}_3)_2$ ), and magnesite ( $\text{MgCO}_3$ ) have indices of 0.01, -0.43, and -0.64, respectively. The positive (greater than zero) index indicates that the water is slightly supersaturated with respect to calcite. These relatively high indices indicate that solid carbonate minerals are probably present and act as a continuing source of dissolved calcium, magnesium, and carbonate (in the form of bicarbonate).

The WATEQF model also calculated the partial pressure of carbon dioxide (CO<sub>2</sub>) in the sample. Changes in the partial pressure will affect the solubility of carbonates. Water, in equilibrium with the atmosphere, has a CO<sub>2</sub> partial pressure of 10<sup>-3.5</sup> atmospheres (atm). Based on the WATEQF results, Site groundwater partial pressures of CO<sub>2</sub> range from 10<sup>-1.7</sup> to 10<sup>-2.1</sup> atm. In this case, calcite and perhaps other carbonate minerals, may precipitate when the water's partial pressure is further reduced (by aeration or air stripping as examples). This precipitation may cause operation and maintenance problems if the precipitation interferes with the treatment process (e.g., plugging of an air stripper tower, precipitation of minerals on well screen openings, etc.).

Due to other changes caused by aerating groundwater, EPA has established secondary drinking water standards for iron and manganese of 0.3 and 0.05 mg/L, respectively. These standards are due to the metallic taste and objectionable precipitates caused by high levels of these metals.

Iron levels (Appendix E-3) above the standard occurred at two locations in the aquifer (W41D - 1.97 mg/L and PW4 - 0.33 mg/L). As the geometric mean iron concentration in the aquifer (Table 7-6) is 0.05 mg/L, iron does not appear to be a compound of concern.

Manganese levels (Appendix E-3) above the standard occurred at six locations (PW5 - 0.094 mg/L, R1 - 0.090 mg/L, W2DR - 0.122 mg/L, W32D - 0.059 mg/L, and W41D - 0.462 mg/L). As the geometric mean manganese concentration in the aquifer (Table 7-6) is 0.02 mg/L, manganese does not appear to be a compound of concern.

### 7.3 SURFACE WATER AND SEDIMENT

Surface water and sediment samples were collected concurrent with groundwater samples by the groundwater sampling team. Samples were collected from gravel pits, used as storm runoff or effluent discharge point. Samples collected were at Ross Labs (1 sediment and 1 water sample), Kirsch Co. Plant No. 2 (2 sediment and 2 water samples), and the Sturgis Foundry Corporation (1 sediment and 1 water sample).

Surface water and sediment samples were collected to assess potential impact of industrial processes on surface water and subsequently on groundwater by recharge of the aquifer by surface water.

CLP analysis (Tables 7-13) detected methylene chloride in three of the four sediment samples and in the laboratory blank. This contamination is believed to be a laboratory contaminant. Sediment and surface water samples from Ross Labs and the Kirsch Company Plant No. 2 did not have other detectable levels of VOCs. Based on this surface water and sediment sampling, these water sources probably do not contribute to the aquifer contamination.

TCE was detected in the surface water sample collected from the Sturgis Foundry Corporation seepage lagoon (W04-5.00 ug/L). The TCE in the Sturgis Foundry Corporation surface water sample (Table 7-14) is probably due to the presence of TCE in the foundry water supply (95.1 ug/L). As indicated by results at wells W6S and MW4, which are located downgradient from the lagoon's radial groundwater flow (groundwater elevations are shown in Drawings 12686-7 through 10), this lagoon is not a source of significant VOC contamination (the maximum TCE concentration at MW4 was 2 ug/L, W6S had no detectable levels of TCE).

## **8.0 CONTAMINATION FATE AND TRANSPORT**

### **8.1 INTRODUCTION**

The fate and transport of potential contaminants of concern (identified in Section 10) are dependent on several factors, including:

- chemical characteristics of contaminant compounds;
- nature of source (i.e., matrix, cover, soil type, etc.);
- source input history (i.e., quantity disposed, time of disposal, etc.); and
- aquifer characteristics (i.e., permeability, heterogeneity, location of water supply wells, etc.).

The identified contaminant constituents, source characteristics, and input histories are described in Section 7.0. Groundwater provides the principal migration pathway by which transport occurs. Groundwater flow and aquifer characteristics are described in Sections 4.0 and 5.0, and contaminant distribution within the groundwater flow system is presented in Section 7.0. This section focuses on the behavior of the identified chemical contaminants within the environment.

Contaminant fate and transport is largely dependent on chemical properties such as solubility, specific gravity, vapor pressure, soil/water partitioning coefficient ( $K_d$ ), and Henry's Law constant. Discussions of attenuation mechanisms refer to groups of contaminants that were identified during the RI. These contaminant groupings are based on chemical compositional similarities, industrial use or application similarities, and/or similar behavior within the environment.

Potential contaminants of concern are identified in Section 10. Occurrence of these contaminants by source area and media is shown in Table 8-1. The major contaminant groups and the specific compounds of concern are as follows:

- BETX Compounds - Partially water soluble products commonly derived from gasoline, oil, and/or hydrocarbon products. Potential BETX compounds of concern are limited to benzene;
- Total Chlorinated Ethenes - These compounds are commonly from industrial solvents (some are solvent breakdown products). Potential ethenes of concern are tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride (VC);



- Total Chlorinated Ethanes - These compounds are also common industrial solvents (some are breakdown products). Potential ethanes of concern are 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, 1,1,1-trichloroethane, 1,2-dichloroethane, and chloroethane. ;
- Single Carbon Chlorinated Compounds - The potential contaminants of concern are bromodichloromethane and chloroform;
- Ketones - Compounds typically found in resins, paint removers, cements, adhesives and cleaning fluids. The potential ketones of concern are limited to 2-butanone;
- Phthalates - Compounds typically associated with plastics and plastic making processes. Potential phthalates of concern are butylbenzylphthalate, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, and di-n-octylphthalate;
- PCBs - Organic compounds typically associated with capacitors and transformers for electronic products. Potential PCBs of concern are limited to Arochlor 1260; and
- Polycyclic Aromatic Hydrocarbons (PAHs) - A group of compounds associated with and derived from coal and oil tars. Potential PAHs of concern are naphthalene, 2-methylnaphthalene, phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(a)pyrene, ideno(1,2,3-c,d)pyrene, and benzo(g,h,i)perylene.
- Inorganic Compounds - Potential contaminants of concern are barium (Ba), chromium (Cr), Copper (Cu), Lead (Pb), and cyanide.

Tables 7-1 and 7-6 summarize the occurrence of each major contaminant group in soils and groundwater, respectively. As discussed in Section 7.0, it is apparent that chlorinated ethenes are the most prevalent compounds detected within each media (soil, soil gas, water). These compounds are also the most commonly encountered contaminants at the City production wells. The fate and transport of these contaminants are largely controlled by physical and chemical properties presented in Table 8-2. These properties also indicate why other compounds, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and priority pollutant metals, are relatively immobile within the environment.

#### 8.1.1 Contaminant Attenuation Mechanisms

The attenuation mechanisms may be divided into saturated and unsaturated zone processes. The major unsaturated zone attenuation mechanisms discussed within this section are sorption (adsorption plus absorption), volatilization, and leaching. Saturated

zone processes include sorption, degradation, and removal by pumping. Prior to discussing the behavior of each major contaminant group within the environment, a general discussion of contaminant attenuation mechanisms is warranted.

### Sorption

Dissolved organic compounds will tend to adsorb onto solid phases that come in contact with the water. Since there is a large solid surface area available in soils, the relative mass of solute adsorbed may be substantial. The amount of contaminant that may be adsorbed by a soil is a function of soil grain size, mineral composition, organic content, solute composition and solute concentration. The adsorption capacity relationship is frequently expressed by the soil/water partition coefficient ( $K_d$ ). This coefficient is the ratio of the water concentration to the soil concentration at equilibrium.  $K_d$  values for specific contaminant compounds can be estimated from octanol/water partition coefficient ( $K_{ow}$ ) (Table 8-2) and the organic carbon content (Karickhoff, et al., 1979; Schwarzenbach and Westall, 1981; and Wilson, et al., 1981).  $K_{ow}$  describes the relative affinity of a solute for an organic in an aqueous phase. Therefore, this parameter may also be used to describe the relative affinity of a contaminant for soil organic matter and water. In general, substances with relatively high log  $K_{ow}$  values also have relatively high  $K_d$  values and are therefore adsorbed to a greater extent than compounds with low  $K_{ow}$  values.

$K_d$  may also be applied to saturated zone contaminant transport as a means of estimating a contaminant's retardation factor ( $R_F$ ). The retardation factor describes the affect of sorption in decreasing the rate of contaminant transport in the liquid phase relative to a conservative or nonreactive species ( $R_F = 1$ ). The retardation factor can be thought of as the ratio of the groundwater velocity to the contaminant velocity, or the ratio of total mass of a contaminant in the aquifer to the mass in solution. For example, a contaminant with a retardation factor of 2 moves at one-half the groundwater velocity and would have 1 gram adsorbed for each gram in solution.

The retardation factor is related to the distribution coefficient according to the following equation:

$$R_F = 1 + (p_b/n) * K_d \quad (1)$$

Where:

$p_b$  = aquifer bulk density ( $g/cm^3$ )  
 $n$  = effective porosity (unitless)  
 $K_d$  = distribution coefficient ( $cm^3/g$ )

Distribution coefficients were calculated for several representative contaminant compounds (Appendix G) based on estimated organic carbon concentrations, and from the compound-specific organic carbon partitioning coefficient  $K_{OC}$  (U.S. EPA, 1986). Based on the calculated  $K_d$  values and assumed aquifer effective porosity ( $n$ ) and bulk density ( $p_b$ ), retardation factors for TCE (Appendix G) were determined to be approximately 1.1 to 1.8.

#### Volatilization

Volatilization may be a significant process resulting in the loss of some contaminants from soils (Thibodeaux, 1979; Lyman and Reehl, 1981; Swallow and Gschwend, 1983). Volatilization depends on several site factors, including soil porosity and moisture content, surface wind speed, temperature, nature of the surface (e.g., hard packed, vegetative cover, paved, tilled, etc.), and contaminant properties, including Henry's Law constant and diffusivity. The process of volatilization involves several steps, including desorption from soils, diffusion in water, interphase mass transfer, and diffusion in air.

Volatilization is an important process in unsaturated soils, because in addition to the water and solid phases, there is an air phase present. The air phase provides a connection to the atmosphere, which acts as a pathway for gaseous phase diffusion of VOCs through the unsaturated zone. A volatile solute will tend to partition between water and air phases, or between solid and air phases. The former equilibrium situation is described by the Henry's Law constant (Table 8-2). The latter situation would be described by an air/solid partition coefficient. However, little published information is available to allow estimation of such a coefficient. In the current situation, it is reasonable to assume that soil moisture sufficient to maintain a thin water film will remain most of time. Therefore,

the air/solid equilibrium is neglected and Henry's Law alone is used to describe the air/water solute distribution.

The substances with relatively high Henry's Law constants (Table 8-2) readily partition into the air phase, so that relatively higher volatilization losses will be observed for these substances. Substances with relatively high diffusivities in air will also show relatively high volatilization losses. There is no simple relationship between the Henry's Law constant and molecular diffusivity. In general, there is a greater difference in Henry's Law constant than in diffusivities between different substances, so the magnitude of the Henry's Law constant may be taken to be the main semi-quantitative indicator of contamination loss through volatilization.

#### Leaching

Leaching of compounds from the unsaturated zone provide a mechanism by which impacts are transferred to the groundwater system. The leachability of hydrophobic chemicals depends on several factors, including the flow rate of water through the contaminated soils and solubility of the chemicals in water. Examination of the data in Table 8-2 indicates that the solubilities for the chemicals listed are variable. In general, the compounds with highest solubilities in water are expected to exhibit the highest losses by leaching.

#### Degradation

Biodegradation may be an important environmental fate, under the proper conditions. Bouwer and McCarty (1983, 1983a), Parsons, et al. (1984), and Kloepper, et al. (1985) have demonstrated in laboratory studies that microbially mediated reductive dehalogenation of chlorinated alkanes and alkenes takes place in environments representative of those found in groundwater systems. Cline and Viste (1984) presented chemical data from several hydrogeologic investigations, demonstrating field trends are consistent with the predictions of laboratory studies.

In general, the above-mentioned investigations suggest that chlorinated parent compounds, such as tetrachloroethene, trichloroethene, and 1,1,1-trichloroethane, can be converted sequentially through loss of a chlorine atom to tri-, di-, or mono-chlorinated species by reductive dechlorination. This type of reaction appears to be microbially mediated, though the precise reaction mechanisms are not well understood. The degradation reactions are favored under anaerobic or anoxic conditions in the presence of a nonhalogenated carbon source (the nonhalogenated carbon source serves as the main food source to sustain the bacterial community). Degradation under aerobic conditions without another carbon source is slow or nonexistent (Bouwer, et al., 1981).

Transformation of chlorinated alkanes and alkenes is, therefore, expected to be slow in the upper layer of the unsaturated zone, where the exchange of atmospheric and soil gases normally creates aerobic conditions. Under anoxic or anaerobic conditions, degradation will still be slow due to the lack of a carbon source which would support normal bacterial metabolism.

#### Overall Mobility

Several chemical properties are related to the mobility of organic chemicals in soil. These properties must be considered together, along with site factors, if an accurate depiction of movement in soils and groundwater is to be obtained. Solubility describes the extent to which a pure chemical dissolves in water. Henry's Law describes the partitioning between water and air.  $K_d$  describes the partitioning between water and soil. Vapor pressure describes the volatility of a pure substance. Density indicates whether a pure substance will sink in or float on water. Melting and boiling points indicate the state or phase of a pure substance at the prevailing temperature. Therefore, possible fates depend on which phases are present. In unsaturated soils, there are solid, gas, and liquid phases present. Gas porosity is dependent on soil moisture, and at a high moisture content, volatilization losses are reduced due to the lower gas permeability. In saturated soils, only liquid and solid phases are present, so sorption and residual saturation become important. Biodegradation may be significant in saturated and unsaturated soils, depending on the prevailing environmental factors relevant to biological activity.

Contaminant removal by groundwater extraction from pumping production wells also constitutes a major contaminant removal process for compounds that are mobile enough to migrate through the groundwater to an extraction point. As shown in Section 7, the production wells are capable of drawing contaminants from as far as 1 mile.

## 8.2 CONTAMINANT MIGRATION/ATTENUATION

### 8.2.1 Chlorinated Ethene Compounds

As stated in Section 7.0, four major chlorinated ethene contamination source areas were identified during the RI. These sources are as follows:

- Kirsch Co. Plant No. 1
- Wade Electric
- Telemark Business Forms
- Sturgis Newport Business Forms

### 8.2.2 Unsaturated Zone Attenuation Processes

Attenuation of chlorinated ethene compounds in the unsaturated zone is dependent on sorption, residual saturation volatilization, and leaching mechanisms. As previously stated, chemical or biochemical degradation reactions are favored under anaerobic or anoxic conditions. These types of conditions do not appear to have existed at a significant level at the source areas. Small amounts of 1,2-DCE (trans and cis), a potential degradation product, were observed in the soils at Kirsch Co. Plant No. 1 and Wade Electric. Compared to the levels of PCE and TCE, the low levels of degradation products indicate that the contaminants contained within the unsaturated soils predominantly reflect parent compound composition rather than degradation products.

### Sorption

As stated in Section 8.1, the potential for sorption of an organic compound is expressed by the soil/water distribution coefficient ( $K_d$ ). Because the amount of organic matter in soil decreases with depth, it is not practical to assign a single  $K_d$  value to a compound.  $K_d$  values presented in Appendix G indicate the sorption potential of several compounds based on the range of expected soil organic content. In general, higher molecular weight chlorinated ethene compounds, such as PCE, possess higher  $K_d$  values and therefore are sorbed more readily than low molecular weight compounds, such as 1,2-DCE. TCE

possesses an intermediate  $K_d$  value and therefore is less likely to be absorbed than PCE under similar soil conditions.

Based on the  $K_d$  dependence on organic carbon shown in Appendix G, it is apparent that soils with high organic carbon content, such as surface soils, are much more effective in sorbing chlorinated ethene compounds than the underlying deposits. This relationship may explain the elevated contamination levels observed at the Kirsch Co. Plant No. 1 and former Wade Electric facilities (the age of the spill would also affect the vertical distribution).

#### Volatilization

Based on the relatively high Henry's Law constants presented in Table 8-2, it is apparent that volatilization is a significant fate for chlorinated ethene compounds contained within the unsaturated zone. Given that PCE has a larger constant ( $2.59 \times 10^{-2}$  atm-m<sup>3</sup>/mole) than TCE ( $9.1 \times 10^{-3}$  atm-m<sup>3</sup>/mole), under similar conditions a greater percentage of PCE may be expected to be lost due to volatilization than TCE or DCE. The fact that PCE has a lower solubility than TCE also enhances the loss of PCE to volatilization rather than to leaching.

Volatilization has likely been an important process in reducing the TCE and PCE levels in the soil. Since some of the source areas impacts appear to be relatively shallow and site soils are generally coarse grained, gaseous diffusion and release to the atmosphere should readily occur.

#### Leaching

Examination of the solubility of various chlorinated ethene compounds in water presented in Table 8-2 indicates solubility constants ranging from a low of 150 mg/L for PCE to a high of 6300 mg/L for trans-1,2-DCE. Therefore, under similar conditions, a much greater mass of trans-1,2 DCE would be expected to solubilize in water than would PCE. Soil/water partition coefficients ( $K_d$ ) presented in Appendix G indicate that PCE is more likely to sorb onto soil particles than TCE or 1,2-DCE. Conversely, TCE and 1,2-DCE are more likely to be desorbed and leached from contaminated soils/residues.

### 8.2.2.1 Chlorinated Ethenes Within the Saturated Zone

#### Introduction

Chlorinated ethene compounds are mobile within the groundwater flow system and have affected City water supply wells PW1, PW2, PW3, and production wells F1, R1, and R4. One major groundwater contaminant plume consisting of chlorinated ethene compounds has been detected within the aquifer. Two smaller plumes were identified below the Wade Electric and Telemark properties in Section 7.0. The plume distribution is shown in Drawing 12686-6.

The plume may be further subdivided into northwestern, western, southeastern, and southern legs according to the production wells affected (R1 and R4, northwestern; F1 and PW3, western; PW4, southeastern; and PW5, southern). An additional leg appears southwest of the plume due to 18 ug/L detected in W39D. Since this southwestern leg is not caused by a production well, this contaminant migration is apparently due to the regional groundwater flow.

#### Migration Processes

Results of soil and groundwater quality monitoring conducted during the RI suggest that chlorinated ethene compounds have been conveyed to the groundwater flow system by the leaching of unsaturated zone contaminant sources. No evidence of a non-aqueous phase liquid (NAPL) were observed at Kirsch Co. Plant No. 1.

Contaminant migration within the saturated zone is a function of several properties listed in Table 8-2. Solubility describes the extent to which a pure chemical compound dissolves in water. If the concentration of a compound exceeds the solubility limit, the contaminant will be present within the aquifer as a NAPL. The migration of a NAPL is generally controlled by the product's density relative to the density of water. A NAPL formed by compounds with a composite density greater than 1.0 g/cc at 20°C would tend to sink within the aquifer, although some NAPL products may also be retained within the upper portions of the aquifer as residual saturation. The density of chlorinated ethene compounds range from 1.62 g/cc for PCE to 1.18 g/cc for 1,1-DCE. Therefore, if these compounds were present at concentrations exceeding the solubility limit, they would be expected to migrate downward into the aquifer until either the NAPL was dispersed into



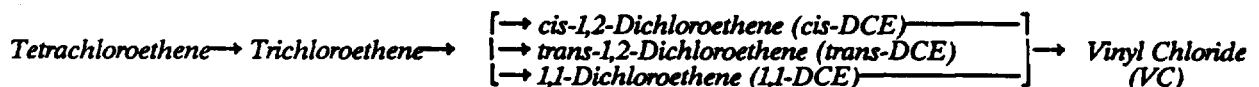
the finer pores of the aquifer, adsorbed on the organic fraction at the soil or a low permeability barrier was encountered, after which the compounds would slowly dissolve into the aqueous phase and would be transported by advection (groundwater flow) or diffusion (migration under a concentration gradient). As discussed in Section 7.0, no evidence of NAPLs were found in the investigation.

#### Sorption/Retardation

Based on the organic carbon partition coefficients ( $K_{OC}$ ) presented in Table 8-2, it is apparent that chlorinated ethene compounds possess relatively low  $K_{OC}$  values and are, therefore, expected to be relatively mobile within the aquifer. Distribution coefficients and retardation factors calculated based on the organic carbon partitioning coefficients and the organic content of the soils are presented in Appendix G. Typical distribution coefficients and retardation factors for this aquifer are 0.013 to 0.13 and 1.1 to 1.8 for TCE and 0.036 to 0.36 and 1.2 to 3.2 for PCE, respectively.

#### Biodegradation

As previously stated, higher molecular weight chlorinated ethene compounds such as PCE and TCE may biodegrade into lower chlorinated ethane compounds through reductive dehalogenation. The typical degradation pathway is as follows:



Degradation by reductive dehalogenation is favored under anoxic or anaerobic degradation in the presence of a carbon source. Based on groundwater samples obtained from the Kirsch Co. Plant No. 1, Wade Electric, and the Telemark Business Forms properties, a small amount of degradation to 1,2-DCE occurs (maximum DCE concentrations: W23S (Kirsch)-11 ug/l; W19S (Wade)-7 ug/l; and W10S (Telemark)-6 ug/l). Wells along the centerline of the plume also suggest that a minor amount of degradation to DCE has occurred (maximum DCE concentrations: W26S-10 ug/l;

W2DR-17 ug/l; and W32D-19 ug/l). Comparing the DCE concentrations to the TCE concentrations, biological degradation appears to have a minor role in contaminant attenuation.

### 8.2.3 Chlorinated Ethanes

Chlorinated ethane compounds, including chloroethane, 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,1,1-trichloroethane (1,1,1-TCA), and 1,1,2-trichloroethane (1,1,2-TCA) have been detected at 18 monitoring locations within the Site. The ethane compounds are frequently detected in association with the chlorinated ethene plumes, but at much lower concentrations than the ethene compounds. 1,1,1-TCA was the most frequently encountered chlorinated ethane compound. 1,1,1-TCA concentrations within the aquifer have ranged from 0.3 to 9 ug/L. The highest overall 1,1,1-TCA concentration was observed at well W34S near Kirsch Co. Plant No. 1 (9 ug/L).

Based on Table 8.2, it is apparent that chlorinated ethane compounds behave similarly to ethene compounds within the environment. In general, ethane compounds tend to be relatively soluble in water and have relatively low  $K_d$  values. Appendix G gives the retardation factors ( $R_F$ ) for 1,1-DCA and 1,1,1-TCA.  $R_F$  values range from 1.02 to 1.9 therefore, ethane compounds are subject to leaching and are mobile within the groundwater. Solubilities range from a high of  $4.5 \times 10^3$  mg/L for 1,1,2-TCA to a low of  $1.5 \times 10^3$  mg/L for 1,1,1-TCA. Chlorinated ethane compounds are denser than water when present at concentrations higher than the solubility limit. Chlorinated ethane compounds also possess relatively low organic carbon and octanol water partition coefficients; therefore, the soil sorption coefficient and retardation factors are also expected to be relatively low, indicating little attenuation by sorption. Henry's Law constants presented in Table 8-2 suggest that the chlorinated ethane compounds are relatively volatile and, therefore, are subject to phase change losses. As with chlorinated ethene compounds, chlorinated ethanes are subject to degradation by reductive dehalogenation. However, degradation products, such as 1,1-DCA and 1,2-DCA, were only encountered at three monitoring locations at very low levels (2 ug/L or less).

### 8.3 BETX COMPOUNDS

BETX or monoaromatic hydrocarbon compounds (benzene, ethylbenzene, toluene, and xylenes) were detected in soils and groundwater at several locations within the City of Sturgis. These compounds are common constituents of gasoline, fuel oil, and other petroleum products. However, these compounds may also be used independently as solvents (i.e., toluene, xylene). Benzene was detected in a few isolated samples at low levels (GW-4 - 2 ug/L, PW2 - 2 ug/L, and W1S - 0.2 ug/L). No ethylbenzene, toluene or xylene was detected in any of the groundwater samples. Due to the isolated occurrence of benzene, discussion of fate of these compounds does not appear warranted.

### 8.4 KETONES

Acetone, 2-butanone, and 4-methyl-2-pentanone were detected during RI groundwater monitoring. However, these compounds are common laboratory contaminants and were detected at low concentrations. Therefore, reported detections are suspect. Discussion of the fate and transport of these compounds does not appear warranted.

### 8.5 SINGLE CARBON CHLORINATED COMPOUNDS

This group includes a variety of compounds, including bromodichloromethane and chloroform, and methylene chloride. These compounds are common refrigerants and low temperature solvents. However, trihalomethane compounds such as chloroform may also result from the chlorination of water rich in organic matter.

Chloroform was the most frequently detected single carbon chlorinated compound. Concentrations ranged from BMDL to 16 ug/L. The compound appears relatively consistently at wells MW1A and MW1B. The potential source of this compound is unknown.

The water solubility of chloroform is 8200 mg/l. Based on this solubility, chloroform is relatively mobile within the groundwater system and is subject to leaching. When present in concentrations exceeding the solubility limit, these compounds are denser than water and, therefore, tend to sink. The single carbon chlorinated compounds have relatively low organic carbon partition coefficients; consequently, soil/water partitioning

coefficients are also expected to be low, indicating minimal sorption and/or plume retardation.  $R_F$  values for chloromethane and chlorobenzene (Appendix G) ranged from 1.02 to 3.0, indicating that these compounds will tend to move with groundwater. Based on Henry's Law coefficients presented in Table 8-2, chloroform has a relatively high value and is, therefore, subject to volatilization losses.

Dibromochloromethane was detected in only two samples (F1-Round 1 and PW-Round 3) at low concentrations (1 ug/l). Due to the isolated occurrence of potential low level contamination, dibromochloromethane does not appear to be a substance of concern.

#### 8.6 PHTHALATES

Phthalate compounds were identified within both groundwater and soil/residue samples. These compounds are classified as semivolatile based primarily on the relatively low Henry's Law constants presented in Table 8-2. Phthalate compounds are common plasticizers and are a constituent of lacquers, plastics, rubber, and coating agents. Due to the common use of plastic and rubber within the laboratory, phthalate compounds are frequently encountered laboratory contaminants. Therefore, phthalate concentrations within the soil samples may be suspect.

Based on available data presented in Table 8-2, it is apparent that the detected phthalate compounds (bis(2-ethylhexyl)phthalate and di-n-octylphthalate) are considerably less soluble than VOCs and will be less mobile in the environment.

Phthalate occurrence was much more pronounced within soil samples (Table 3-3) than in groundwater. This is consistent with the compounds' higher attenuation and lower mobility characteristics.

Based on these observed concentrations, phthalates with relatively low solubility, such as butylbenzylphthalate, are expected to remain absorbed on soil and residue materials. These compounds are not very volatile; therefore, losses due to phase change should be minimal. The major potential for off-Site migration is either through erosion and transport of contaminated sediments or windblown migration of particulate contaminants.

### 8.7 PCBS/PESTICIDES

Polychlorinated biphenyl compounds (PCBs), specifically Arochlor 1260, were detected in four soil samples at low levels (SB19-04 - 290 ug/kg, SB26-0.5 - 1,500 ug/kg, SB30-0.5 - 420 ug/kg, and SB31-0.5 - 650 ug/kg). No PCBs were detected in groundwater. PCBs are very immobile.  $R_F$  values for Arochlor 1260 range from 320 to 3,200 indicate that the PCBs will not migrate from the soil.

No pesticides were detected in the soil or water. Pesticides do not appear to be substances of concern.

### 8.8 POLYCYCLIC AROMATIC HYDROCARBONS (PAHS)

Based on the RI, PAH compounds presently appear to be concentrated within the shallow unsaturated zones.

PAH compounds consist of higher molecular weight hydrocarbon compounds typically derived from fuel oils, kerosene, coal tars, wood preservatives, and a variety of other petroleum products. In general, these compounds tend to have relatively low solubilities in water and are less mobile than VOCs. PAH compounds generally tend to be strongly sorbed by soil organic content as indicated by the high organic carbon partition coefficients. No PAH compounds have been detected within the groundwater which is consistent with their high attenuation and low mobility properties.  $R_F$  values for anthracene and dibenzo(a,h)anthracene range from 1.6 to  $4.2 \times 10^6$  which indicates that, while some compounds are relatively mobile, most are very immobile. PAH compounds have low Henry's Law constants and do not readily volatilize at ambient temperatures. Erosion of contaminated sediments is a potential migration pathway for PAH compounds.

At Kirsch Co. Plant No. 1, naphthalene, 2-methylnaphthalene, dibenzofuran, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, and benzo(g,h,i) perylene were detected in the W42S soil sample collected at a depth of 2.5 ft. The total PAH concentration for this sample was 2,500 ug/kg. No other soil samples collected at Kirsch Co. Plant No. 1 contained detectable levels of PAHs.

At Wade Electric, PAHs were detected in soil borings SB11 and SB12. The most contaminated sample, SB11 at a depth of 1.5 ft, contained phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene, at a total PAH level of 750 ug/kg.

At Telemark Business forms, PAHs were detected in SB16 at a depth of 1.5 ft. The sample contained 2-methylnaphthalene and phenanthrene, at a total PAH level of 30 ug/kg.

### 8.9 INORGANIC CONTAMINANTS

The majority of the remedial investigation sampling activities focused on identifying sources of VOCs at contaminated City production wells. However, as noted in Section 7.1.3, inorganic groundwater quality differences were also observed within the Site. Some of these differences appear to be attributed to natural background variation in the chemical composition of area groundwater.

Selected groundwater and soil/residue samples were analyzed for priority pollutant metals and cyanides during Rounds 2 and 3 (groundwater) and Phase II (soil/residue) sampling. In addition, groundwater samples obtained during Rounds 1 and 2 were analyzed for major inorganic indicator constituents (refer to Appendix E-7).

Elevated groundwater concentrations of barium, chromium, copper lead and cyanide have been detected at isolated locations. The fate and transport of inorganic species are primarily dependent on two primary mechanisms: precipitation/dissolution and sorption/desorption. Based on results from samples collected from wells in the vicinity of observed elevated concentrations, transport of these species appear to be restricted to the immediate vicinity of their occurrence.

#### Precipitation

Precipitation of a mineral phase is generally controlled by solubility. Therefore, the thermodynamic behavior of various species may be used to predict the most stable phase that will form in a geologic environment. However, the thermochemical behavior of

numerous trace elements (Pb, Cr, Cu, etc.) are not adequately described within the literature, therefore, the evidence for the existence of solubility-controlling solid phases is often indirect, such as comparison of ion activity products to solubility products. Observed and speculated solid/mineral phases which may control the aqueous concentrations of priority pollutant metals are presented in Table 8-3. Hydroxide and carbonate solids are more soluble at low pH values. Therefore, these phases are important in alkaline geologic materials ( $\text{pH} \geq 7.0$ ). Based on the observed pH range of groundwater beneath the City (7.0 to 7.4 S.U.) and the low concentration of the trace constituents, hydroxide and carbonate precipitates are not favored.

#### Sorption/Desorption

Sorption/desorption reactions are dependent on the geologic matrix, the hydrochemical environment, as well as the specific valence state and ionic radii of the adsorbed element. Important adsorbent media include the following:

- hydrous oxides of Al, Fe, and Mn;
- amorphous aluminosilicates;
- organic matter; and
- lattice silicates or clay minerals.

Hydrochemical conditions influence adsorption by: 1) controlling ion speciation, 2) providing ions that compete for adsorption sites, and 3) affecting the net surface charge on amphoteric adsorbents (e.g., Fe and Mn oxides, amorphous aluminosilicates) and affecting base saturation and exchangeable acidity of cation exchange materials. Element speciation is controlled primarily by solution pH,  $\text{eH}$ , and ion composition. Research indicates that, for the most part, only uncomplexed ions (e.g.,  $\text{Cu}^{2+}$ ), rather than complexed ions (e.g.,  $\text{CuSO}_4$ ,  $\text{CuCO}_3$ ), are adsorbed. Thus, hydrochemical conditions in leachate or groundwater which favor complexation may reduce adsorption. Similarly, solution redox potential controls the valence of redox sensitive elements. For some elements (e.g., Cr) different valence states exhibit markedly different adsorption behavior. In addition to affecting solution speciation of cations via complexation, major

leachate anions (e.g.,  $\text{SO}_4^{2-}$ ) may compete for available sorption sites with contaminants of similar chemical behavior (e.g.,  $\text{SeO}_4^{2-}$ ,  $\text{CrO}_4^{2-}$ ), thus, reducing the sorption of each individual constituent. Most specific adsorbents (e.g., Fe, Mn oxides, amorphous aluminosilicates) have a pH-dependent surface charge. These constituents are positively charged at pH values below their point of zero charge (PZC), and negatively charged above. Thus, decreasing groundwater pH increases positive charge and favors anion retention, while increasing pH encourages cation adsorption.

The cationic elements are sorbed specifically and by ion exchange. With the exception of Na and Ba, the specific sorption process predominates for most trace constituents at lower environmental concentrations ( $< 10^{-5}$  M [molarity]). Ion exchange dominates when the specific sorption capacity is exceeded. The affinity of specifically adsorbed cations for hydrous oxides decreases in the following order:  $\text{Pb} > \text{Cu} > \text{Zn} > \text{Ba} \geq \text{Cd}$ . Some cationic elements, notably Cu and Hg, are strongly complexed by particulate organic materials. The sorption of most cationic elements increases with an increase in pH. Thus, the cations are significantly more mobile under acidic than basic conditions (Battelle, 1984).

Hydrogen cyanide (HCN) is a weak acid that will form complexes with other metal ions in solution. HCN has an acid dissociation constant of  $4.8 \times 10^{-10}$  which means that at a pH of about 9.5, 50% of HCN is ionized (i.e., 50% exists as  $\text{CN}^-$  and 50% exists as HCN). At the pH of the aquifer (pH range 7-8), over 90% of the HCN is in the undissociated form. The soils and aquifer will provide little attenuation for undissociated HCN and the HCN will flush through the soils and through the groundwater.

Dissociated HCN ( $\text{CN}^-$ ) and other ligands (e.g.,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{F}^-$ , and organics) can form stable aqueous complexes with cations (e.g.,  $\text{Pb}^{2+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Hg}^{2+}$ ) which will reduce free cation activity and hence element adsorption (the ligands will become more mobile). The presence of macro ions (e.g.,  $\text{Ca}^{2+}$ ,  $\text{Na}^+$ ) and specifically absorbing ions (e.g., Cu, Zn, Cd) in solution also tend to reduce adsorption through competition for cation exchange sites and specific adsorption sites, respectively, which also will tend to increase ligand mobility.



## **9.0 GROUNDWATER MODELING**

### **9.1 PURPOSE**

The groundwater flow model of the Site was constructed for the following purposes:

- for use during the RI to help direct the investigation and evaluation of potential contaminant migration routes;
- to quantify the groundwater flow system and potential contaminant migration routes to help validate the conclusions of the RI;
- to evaluate potential remedial actions considered in the FS; and
- to evaluate potential exposure routes in the risk assessment (Section 10).

This section describes the models used to simulate the groundwater, the physical parameters (boundary conditions and hydraulic parameters) of the flow model and the calibration of the model to observed groundwater head and contaminant migration pathways. The remedial action uses of the model are described and presented in the FS.

Preliminary stages of the model were also used in presentations to City officials in an effort to describe the current problem and the potential effects of planned expansion of the municipal well system. Simulations were conducted to evaluate several alternate well locations. The City ultimately selected the Thurston Woods Park as the location of a new municipal well.

### **9.2 HYDROGEOLOGY CONCEPTUAL MODEL**

The geology and groundwater flow system within the City is described in detail in Section 5 of the RI report. This summary provides a general conceptual model used as a basis for construction of the groundwater flow model simulating the Site conditions. Groundwater flow occurs primarily within the glacial deposits underlying the City. Cross Section A-A' (Drawing 12686-15), for example, shows the presence of three sand and

gravel outwash deposits which form the aquifers in the Site vicinity. These three aquifers are separated by two discontinuous confining layers formed of glacial lacustrine or till deposits. The base of the flow system is formed by the Coldwater Shale or a dense clay till overlying the shale. The municipal and industrial water supply wells pump from the lower sand and gravel aquifer.

Horizontal groundwater flow occurs principally in the three outwash deposits due to their relatively high hydraulic conductivity. Downward vertical flow is induced from the upper and middle aquifers into the lower aquifer, because of the water supply wells withdrawing water from the lower aquifer. This downward flow is somewhat restricted by the presence of the confining units between the sand and gravel deposits. Therefore, flow in the two upper aquifers is generally toward areas where the confining units are relatively thin (in the vicinity of water supply wells R1 through R4) or where these units are non-existent (in the vicinity of well nest W2). The downward vertical flow from the upper aquifers to the lower aquifer occurs principally within these areas. Flow in the lower aquifer is locally dominated by the pumping rates and locations of the municipal and industrial water supply wells. It appears that regional flow in this lower aquifer is from the northeast toward the southwest.

Recharge to the groundwater flow system in the Site occurs primarily from rainfall. The recharge rate is relatively high because the surface deposits in this area are sand and gravel. Recharge is estimated to occur between 8 and 12 in./yr.

The only surface water bodies present within the City are absorption ponds, operated by Sturgis Foundry, Kirsch Co. Plant No. 2, and Ross Laboratories. The Sturgis Foundry pond was used for the disposal of cooling water used in the plant. This cooling water was obtained from the Foundry pumping well (well F1 on Drawing 12686-5). Therefore, the recharge rate from this absorption pond is approximately equal to the pumping rate from the well. Section 5 of this report discusses the absorption ponds further. Numerous other surface water bodies are present in the vicinity of the City, including Fawn River to the southeast and south, the Nye Drain to the south, and two chains of lakes to the northwest and northeast. The surface water bodies appear to act as groundwater discharge areas.

### 9.3 MODEL SELECTION AND DESCRIPTION

The USGS Three Dimensional Finite Difference Groundwater Flow Model (MODFLOW: McDonald and Harbaugh, 1988) was chosen to simulate the groundwater flow system characteristics at Sturgis because of its ability to effectively handle the large model area; the problems of three dimensional groundwater flow and complex stratigraphy; and the transient nature of the municipal and industrial pumping well field. MODFLOW solves a finite difference approximation to the differential equation describing groundwater flow. MODFLOW is a well documented, standard method in groundwater modeling. For a more detailed description of MODFLOW, please refer to its documentation.

PATH3D, a three-dimensional advective particle tracking model, was used to help interpret results of the groundwater flow model. The program, developed at the Department of Geology and Geophysics at the University of Wisconsin (Zheng, 1989), computes groundwater flow direction using the properties of the flow system (MODFLOW input) and the hydraulic head computed by MODFLOW at each cell for each time step in the model. Flow paths are selected by specifying the cartesian coordinates for "particles" of groundwater. Starting with specified initial positions, PATH3D computes the trajectory of each particle through the domain of the model, moving the particle both horizontally and vertically depending on the hydraulic conductivity data input to the flow model and the resulting heads.

Trajectories which are computed by PATH3D show how particles move under advective processes in relation to the heads that are computed by the flow model. Zones of particle trajectories (in plan view) are shown on Drawing 12686-25.

### 9.4 MODEL PHYSICAL DIMENSIONS

The physical dimensions of the model measure 32,000 ft east to west by 34,900 ft north to south, as shown on Drawing 12686-22. The model size and orientation were selected so that surface water features surrounding the City would fall on the model boundaries. The model is also oriented so that the principal directions of geologic deposition are parallel to the model rows and columns, to satisfy the model assumption that the principal axes of permeability are oriented parallel to the model's rows and columns.

The hydraulic boundaries (e.g., Fawn River to the south) form the necessary boundaries to the flow simulated within the model. Model grid spacing ranged from 2,700 ft (rows) to 2,800 ft (columns) at the model boundaries, to a uniform spacing of 200 ft by 200 ft in the interior of the model. This uniform spacing provides higher resolution in the vicinity of the municipal and industrial water supply wells, enabling the model to more accurately simulate the flow system and contaminant migration within that area.

The model consists of five layers, which simulate the three principal sand and gravel aquifers (model layers 1, 3 and 5) and two confining units (model layers 2 and 4). Specifically, the model layers equate to the geologic units shown on cross section A-A' (Drawing 12686-15) as follows:

<u>Model Layer Number</u>	<u>Geologic Unit</u>	<u>Hydrologic Function</u>
1	Upper Outwash	Upper aquifer in model
2	Upper Till	Upper confining unit in model, where present
3	Middle Outwash	Middle aquifer in model
4	Intermediate Till	Lower confining unit in model, where present
5	Lower Outwash	Lower aquifer in model (used by all water supply wells in the City)

Where the confining units are shown to pinch out (e.g., at well nest W2 on cross section C-C', Drawing 12686-16) the hydraulic parameters of model layers 2 and 4 are changed to simulate portions of the sand and gravel aquifers.

Surface water features are simulated in the model using the MODFLOW river node input package. A total of 244 river nodes have been input to the model, to serve as the primary flow system boundaries. The principal surface water features simulated in the model are the Fawn River, Nye Drain, Minnewaukan Lake, Omena Lake, Grey Lake, Stewart Lake, Sweet Lake, Cade Lake, Baker Lake, Dark Lake, Williams Lake and Lee Lake. River nodes in the model either accept groundwater discharge from the simulated aquifer or contribute recharge to the aquifer depending on the head specified in the river

node and the head computed in the aquifer. A river bed conductance parameter is used in the model to simulate resistance between the aquifer and the surface water body.

No-flow boundaries surround the model on all sides. Surface water features near the model boundaries (simulated as river nodes) serve as functional hydraulic boundaries (see Drawing 12686-22) either receiving water from the aquifer or discharging water to the aquifer, depending upon the stage in the river nodes and the head in the aquifer. The Fawn River is present along the southern half of the eastern model boundary and along the entire southern model boundary with the exception of model columns 1, 2 and 3. The Fawn River is considered to be a functional boundary in the model.

The model boundary between Fawn River and Minnewaukan Lake (see Drawing 12696-22) has no surface water body between the no-flow boundary on the edge of the model, and the pumping wells within the City of Sturgis. This no-flow boundary appears reasonable in this area, because it is parallel to what is expected to be a flow line toward the Fawn River from the topographic high to the north, and it is a large distance away from stresses applied to the lower aquifer by municipal and industrial well pumpage.

The northern half of the eastern and western model boundaries, and the entire northern model boundary are separated from pumping in the City of Sturgis by two chains of lakes, described above. Therefore, the no-flow boundaries on the northern half of the model do not appear to have an affect on pumping within the City of Sturgis.

## 9.5 AQUIFER PARAMETERS

Aquifer parameters were developed by mapping the physical limits and thicknesses of each unit and assigning hydraulic properties to each layer to compute model input parameters. The first step was to establish the topographic surface for each layer in the model. The contact between each aquifer and the overlying and underlying confining units were mapped. These maps were then interpolated onto the model grid, shown on Drawing 12686-22. Layer thicknesses were computed by subtracting the elevations at the top of one surface from the elevations of the surface immediately below it. Aquifer

parameters used to develop the model input parameters were based on analyses conducted during the RI field investigation and calibration of the model to observed conditions. Aquifer parameters used in the final calibrated model are summarized in Table 9-1. The use of these parameters to develop model input is described below.

Vertical resistance between model layers was computed using the weighted average of the vertical hydraulic conductivity from one layer to another for each cell of the model. The equation used for computing the weighted average is:

$$VC(i) = \frac{2}{\frac{Delz(i)}{KV(i)} + \frac{Delz(i+1)}{KV(i+1)}} \quad (2)$$

Where:

- VC(i) = vertical resistance from layer(i) to the next lower layer
- Delz = vertical thickness of the layer
- KV = vertical hydraulic conductivity of a layer
- i = a layer number
- i + 1 = the next lower layer

The vertical resistance of each layer was modified during the calibration phase, within limits reasonable for the soil types present, to obtain a match with observed head conditions. For example, in areas with significant head differences between the shallow and deep aquifers, such as near well nests W-6 and W-8, the resistance between layers was raised, if necessary, to match observed conditions. In areas with little vertical gradient, such as near well nest W-2, the resistance was lowered between layers. Changes to vertical resistance were made to maintain consistency with the interpreted geology and observed soil conditions.

Transmissivity for layers 2 through 5 for each cell was computed by multiplying the layer thickness by the bulk hydraulic conductivity of the cell. The hydraulic conductivity of layer 1 was input directly to the model, because it was simulated as a water table aquifer. The hydraulic conductivity of layers 1 and 5 were adjusted during the calibration phase, within the tested limits, to obtain a match with observed head. Table 9-1 summarizes the final values used in the calibrated model.

Hydraulic conductance across the river and lake bottoms was calculated for each cell where a lake or river was present, as:

$$C = \frac{LWK}{m} \quad (3)$$

Where:

- C = hydraulic conductance between the lake/river and the aquifer
- L = length of a lake/river in the cell
- W = width of the lake/river in the cell
- K = vertical hydraulic conductivity of the lake/river bed
- m = the lake/river bed thickness

The vertical hydraulic conductivity and bed thickness used (see Table 9-1) is based on experience in similar environments for obtaining a reasonable head loss across a 1-ft thick bed.

Recharge was uniformly applied to the uppermost active cell within the domain of the model. Recharge was selected based on the rainfall for the area and the type of soils present at the ground surface. Recharge was modified in the model calibration phase to arrive at a best fit to observed conditions. Recharge in the final, calibrated model is shown in Table 9-1.

## 9.6 PUMPING RECORDS

Pumping rates input to the model were developed from pumping records supplied by the City, Ross Laboratories and Sturgis Foundry Corporation for the period January 1977 through December 1988. The City provided actual volume pumped per day and per month for individual municipal wells for this period of time. Sturgis Foundry provided the total pumped per month for its well during the period of operation through June 1987. Ross Laboratories provided total volume pumped from its well field and the number of hours of operation for each of its wells (wells R1 through R5) on a per-month basis. The actual rates for the Ross Laboratory wells was computed based on the rating curve for the individual well pump, and the approximate head the well was pumping against (based on personal communication with the Plant Engineer). Figure 1 shows the pumping profiles for these wells from January 1977 to December 1988.

The transient groundwater flow model was simulated between January 1950 and December 1988 in increments, referred to as stress periods. Each well was simulated in each stress period so that the total volume pumped in the model's stress period was equal to the volume recorded to have been pumped in that time frame.

Groundwater flow was simulated between January 1950 and December 1976 using estimated pumping rates for each of the operating production wells. The first stress period in the model (1950 to 1958) used the average pumping rates for the City production wells existing at that time (PW1, PW2 and PW4), and the average 1977 pumping rates for Ross Laboratory wells R1 and R2. Wells PW1 and PW2 are shown as PW2 on Drawing 12686-5 through 13 and 12686-21 through 25 due to their proximity to each other.

The second stress period (1959 through 1976) was simulated by adding the average 1958 pumping rate for City Well PW3 and the average 1977 pumping rate for Ross Laboratory well R3 to the pumping rates for the first stress period. The remaining stress periods (stress periods 3 through 50), from January 1977 through December 1988, were simulated using pumping rates averaged over a 3-month time block per stress period.

#### 9.7 MODEL CALIBRATION

Groundwater levels measured at monitoring wells between December 1987 and November 1989 were used to test the calibration of the flow model. Simulated heads were compared with observed heads at well nests W1, W2, W6, W8 and W26 for this time period. Figures 2 through 4 are observed versus simulated head history profiles for these five well nests. To further test the calibration of the flow model, simulated water table and potentiometric surfaces of December 1988 were compared to the surfaces developed from heads measured in the field in January 1989. Drawings 12686-23 and -24 are simulated water table and potentiometric surface maps, respectively, and can be compared to observed water table and potentiometric surface maps, Drawings 12686-8 and -12, respectively. These maps are not identical, because the observed conditions maps are:



- interpretations based on a limited number of observations;
- affected by small variations in aquifer properties in the vicinity of each well; and
- affected by shorter term variations in pumping than the simulated three month averaged pumping rates.

Although these maps are not identical, the principal groundwater flow directions and the heads in critical areas are very similar.

The groundwater contaminant plume, as interpreted from analysis of Round 4 groundwater samples collected in August 1989 (Drawing 12686-6), was used to test the calibration of the particle tracking model. Drawing 12686-25 shows the extent of groundwater migration routes from three potential sources of groundwater contamination. These groundwater migration routes are the result of a non-dispersive, advective groundwater flow route. This means that dispersion due to aquifer heterogeneity, mechanical dispersion and chemical diffusion is not simulated. Therefore, the actual groundwater contaminant plume may be larger (wider) than simulated by the particle tracking model. However, the principal contaminant migration routes, and the zones of highest contamination, should migrate along the approximate migration routes identified by the particle tracking model.

#### 9.7.1 Model Sensitivity

The model is sensitive to vertical conductance across both upper and lower confining units. Increasing conductance in the upper confining unit in the vicinity of areas of low vertical flow resistance had the effect of reducing heads in that layer. Similarly, adjusting vertical conductance between Layers 3 and 4 in the vicinity of the low vertical flow resistance area had the effect of increasing heads in Layer 5, and providing a strong hydraulic connection with the upper and lower aquifers, resulting in the migration of particles starting in the upper aquifer and terminating at the pumping wells.

The model is also sensitive to changes in transmissivity in layer 5. Factors of 0.2, 0.5, 1.0, 2.0 and 5.0 were applied to the layer 5 transmissivity matrix. The model was run in steady state for each factor and head elevation versus the transmissivity factor was examined for each of the wells used in the flow calibration. Generally, a linear relationship existed

between head and transmissivity.

## 9.8 FLOW SYSTEM SIMULATION

Once hydraulic properties of the aquifer were established, the model was started using heads estimated in a steady state run with the 1950 pumping rates. The model was run for 39 years to obtain a head history profile at specified well nests and to obtain a head file for use in PATH3D.

PATH3D runs considered three distinct potential source areas where groundwater contamination was documented to have occurred:

- Kirsch Co. Plant No. 1;
- Wade Electric; and
- Telemark Business Forms.

Each of these were considered a circular source with a 200-ft radius, centered around specific cell locations. The particles were inserted at the water table at each location. Particles were added to the flow system at 5-year increments and allowed to migrate under the transient flow system conditions. Because of the variable nature of the pumping rates, the groundwater flow system changes through time. Each particle was tracked through the aquifer under the influence of the transient aquifer flow system. The transient flow system caused the particles to migrate in different routes at different travel times, resulting in the three divergent legs of the migration route from Kirsch Co. Plant No. 1, shown on Drawing 12686-25. Particles migrating from Wade Electric and Telemark Business Forms showed little or no change in migration routes due to transient flow conditions.

## 9.9 DISCUSSION OF RESULTS

### 9.9.1 Flow System

The results of the simulation indicate that the aquifer is transient and affected by the positions and pumping rates of the municipal and industrial water supply wells. The flow system is dominated by the well field. The presence of a low vertical flow resistance window in both the upper and lower confining units (see Cross Section B-B', Drawing 12686-16) creates a sink in the flow field in the upper and middle aquifers. Groundwater

flow through this window creates a depression in the water table surface, as seen in the observed water table maps (e.g., Drawing 12686-8) as a closed 866 ft contour line around well nest W2. The simulated depression near well nest W2 is not as distinct, but is shown as the 866 ft contour wrapping around well W2 (Drawing 12686-23).

The changes in groundwater levels, both observed and simulated, are shown in Figures 1 through 4 for well nests W1, W2, W6, W8 and W26. These graphs show that the simulated groundwater head was typically within 1 to 2 ft of the observed conditions during the entire record of observed water levels, except at well W6S. Well W6S is screened within a fine-grained material adjacent to the Sturgis Foundry absorption lagoon. Therefore, the head at this well was highly sensitive to the actual absorption pond recharge rate and very small changes in the permeability of the fine-grained material in this area. For example, changing the permeability of this area by only a factor of two raised the simulated head to over Elevation 880 ft MSL. However, recreating the head at well W6S is not critical to accurately simulating the groundwater flow in the principal water supply aquifer under the City.

#### 9.9.2 Contaminant Migration

Contaminant migration simulated by inserting particles at Kirsch Co. Plant No. 1 were shown to migrate toward the center of the City. This was consistent with observed conditions showing contaminants present at well nests W26, W35 and W2. Drawing 12686-25 shows the migration route splits into three separate directions. This separation occurs during three separate times. The principal migration route was toward City well PW2 during its operation. When City well PW2 was turned off, the migration route shifted toward the Ross Laboratories well field. This diversion of the contaminant migration route away from City well PW2 was consistent with the observation that after a period of non-use, City well PW2 initially pumped clean water, with the chlorinated ethene concentration increasing through time, as the plume was pulled back toward the well.

During periods when City well PW2 was off or pumping at very low rates (see Figure 1 for the period 1984 through 1989), the particles originating at Kirsch Co. Plant No. 1 migrated primarily toward Ross Laboratories wells R1 and R2. The contaminant migration route from Kirsch Co. Plant No. 1 also extended through wells W32D and W41D where high concentrations were also shown. The leg of the migration route from Kirsch Co. Plant No. 1 extending toward well PW5 consisted of only a very few number of particle tracks, indicating that at times when PW5 was pumping at relatively high rates and the Ross Laboratories well field was pumping at relatively low rates, a small amount of contamination may have been induced to move toward City well PW5. The small number of particle tracks moving toward City well PW5 indicated that the concentration in this leg of the plume would be very small. Therefore, even though some contaminants may have migrated in the direction of City well PW5, the resulting impact should be negligible, unless current pumping conditions in City wells PW4 and/or PW5 increase while pumping at the Ross Laboratories wells decrease.

The particles initiated at the Wade Electric facility migrated to the north through the upper aquifer and then vertically downward in the vicinity of well W32D where no confining layer was observed. After entering the lower aquifer, groundwater flowed toward City well PW2 while it was pumping. After discontinuing use of City well PW2, particles from the Wade Electric facility migrated toward the Ross Laboratories well field.

Particle tracking was also simulated for the groundwater contaminants observed at Telemark Business Forms. The plume that developed migrated toward the Ross Laboratories well field.

## **10.0 BASELINE RISK ASSESSMENT**

The purpose of the Baseline Risk Assessment is to characterize the nature and estimate the magnitude of potential risks to public health and the environment which may be caused by exposure to contaminants identified at the Site. The risk assessment process involves the identification of contaminants of potential concern, routes of contaminant migration and populations (human or ecological) which may come in contact with the contaminants. This information is then integrated to estimate contaminant exposure level for a given population, which in turn, is compared to toxicity information to evaluate potential health and environmental risks.

The assessment is based on the premise that no action will be taken at the Site to remediate areas of contamination and that the existing level of contamination will persist in the future. The assessment considers risks which may currently exist at the Site and considers possible future land use changes which could lead to additional risks.

This assessment was performed in accordance with guidelines developed by the U.S. EPA (EPA 1989 a and b) for conducting risk assessments at Superfund Sites. Guidelines developed for the State of Michigan (MCEQ 1990) were also applied.

Information acquired during the remedial investigation (RI) of the Site provides the basis for the risk assessment. For a detailed discussion of RI activities and findings, the reader is referred to earlier sections of this report.

This assessment is comprised of the following sections:

- Identification of Chemicals of Potential Concern
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization
- Environmental Assessment

The first four sections of this assessment pertain to the evaluation of potential risks to public health. The environmental assessment focuses on potential adverse impacts to the ecology of the Site and surrounding area.

#### **10.1 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN**

Chemicals considered in the Baseline Risk Assessment are those which are present as a result of chemical releases which have occurred at the Site and are termed "chemicals of potential concern". To identify these, chemicals present in soil and groundwater samples are distinguished from those which may naturally be present (site background) and those which can be unintentionally introduced into samples through sample collection or laboratory analysis. Further, consideration is given to the frequency of occurrence of the chemical at the Site. Those infrequently identified may not be significant in view of overall Site contamination. Chemicals considered to be of potential concern are evaluated further in the risk assessment.

##### **10.1.1 Chemical Analysis of Site Media**

A detailed characterization of contaminants identified at the Site is presented in the RI report, including a description of the number and location of soil and groundwater samples collected (RI Report, Section 3.0), and a discussion of the results of chemical analyses of these samples (RI Report, Section 7.0).

The chemical analyses of samples were performed through the Contract Laboratory Program and have been evaluated to assess their usability in accordance with U.S. EPA guidelines for validation of organic and inorganic analyses of environmental samples (EPA 1988a and b). Data used in the present risk assessment include unqualified data and data which represent estimated quantities (qualified with J). For a description of the evaluation of data quality, refer to Section 6.0 of the RI report. Table 10-1 summarizes the analytical results by indicating the minimum and maximum concentrations of detected analytes and the number of sampling locations where analytes were detected.

#### 10.1.2 Chemicals of Potential Concern

The following describes the rationale for selection or exclusion of compounds as chemicals of potential concern for further evaluation in the risk assessment. Two primary criteria were used to evaluate identified chemicals; comparison with background conditions and an evaluation of possible adulteration of samples during sample collection or laboratory analysis.

Organic chemicals detected in groundwater and soil samples were considered to be above natural background conditions and present either as a result of an environmental release or as the result of sample contamination, occurring during sample collection or laboratory analysis. Some organic analytes released to the environment, however, may be present as a result of intentional human activities (e.g., trihalomethanes from water chlorination) and may be typical of urban areas. Nonetheless, these chemicals were generally considered as chemicals of potential concern. Most inorganic analytes however, are natural constituents of groundwater and soils. To determine if inorganic analyte concentrations appeared to exceed what is expected to occur naturally, chemical data were compared with data from samples considered representative of background conditions. The background concentrations of inorganic analytes in Site soil and groundwater are presented in Table 7-3. Analytes at concentrations that appeared to exceed background concentrations were selected as chemicals of potential concern.

The potential for a detected analyte to be the results of sample contamination was determined by comparing sample results with the results of laboratory and field blanks. Compounds consistently identified in blanks were not selected as chemicals of potential concern.

In addition to these two criteria, the frequency with which an analyte was detected was evaluated. In general, analytes detected in only one of all samples analyzed were not selected as chemicals of potential concern, because they were not considered significant with respect to overall site contamination.

Table 10-2 and the following discussion summarizes the evaluation of identified analytes as chemicals of potential concern.

#### Analytes Identified in Groundwater

All organic chemicals detected in groundwater, with the exception of acetone, 2-hexanone, 4-methyl-2-pentanone and benzoic acid, were considered chemicals of potential concern. Acetone was identified in laboratory and field blanks associated with some, but not all, samples. Also, acetone was detected in only 5 of 91 groundwater samples at low concentrations (5.0 ug/L or less). For these reasons, acetone was considered an artifact and not representative of Site contamination. 2-Hexanone (0.6 ug/L), 4-methyl-2-pentanone (0.7 ug/L) and benzoic acid (4.0 ug/L) were each detected at only one of 91 locations. These compounds were not considered chemicals of potential concern, because of their infrequent detection at low concentrations.

The evaluation of several organic chemicals considered chemicals of potential concern should be interpreted with reservation. Two phthalate compounds, bis(2-ethylhexyl)phthalate (BEHP) and di-n-octylphthalate, were detected at 10 and 4 of 26 sample locations, respectively. These chemicals were not present in laboratory method blanks, but are nonetheless common laboratory or field sampling contaminants and may not actually represent Site contamination. Other compounds considered chemicals of potential concern were periodically identified in some blank samples. These include members of the trihalomethane class; chloroform, bromodichloromethane and dibromochloromethane. Their presence in investigative samples may be the result of field or laboratory contamination. The presence of these compounds in samples from municipal wells may also be the result of groundwater chlorination practices.

Groundwater samples from well W11S and municipal well PW6 were considered representative of background conditions for groundwater quality with respect to inorganic constituents (Table 7-3). Barium concentrations appeared to be elevated at several wells (e.g., W42S, W26S and possibly GW7, and W37I) compared to concentrations in samples from background wells. Therefore, this element was selected as a chemical of potential concern. Chromium concentrations at wells W10S and W23S and cyanide concentrations at wells W19S, W23S, W34S, and possibly W2DR also appeared to exceed background levels. These constituents were selected as chemicals of potential concern. Both iron and manganese were substantially elevated at only one location, well GW7, and were not selected as chemicals of potential concern. Other inorganic analytes detected appeared to be within the background range of concentrations.



#### Analytes Identified in Subsurface Soils

All organic chemicals identified in subsurface soils were considered chemicals of potential concern, with the exception of those described below. Several organic compounds identified in subsurface soils were not selected as chemicals of potential concern, because they were present in some laboratory and field blanks and considered to be likely an artifact of sample collection or analysis. These include acetone and methylene chloride. Toluene was consistently identified in samples from most locations and depths. However, no relationship between toluene concentration and sample location or depth was apparent. In addition, as is described in Section 6.0, this compound was determined to be a contaminant of the sample containers. It was therefore not selected as a chemical of potential concern. A number of other compounds were detected at only one sample depth from only one soil boring location. Based on their infrequent occurrence at the Site, these compounds were not considered chemicals of potential concern and likely represent background conditions for urban industrialized areas. They include: benzene, ethylbenzene, and xylenes detected (4.0, 3.0 and 6.0 ug/kg, respectively) at location SB02 at a depth of 2.5 ft; bromomethane, detected (5.0 ug/kg) at location SB06 at a depth of 6 ft; carbon tetrachloride, detected (9.0 ug/kg) at location SB13 at a depth of 20 ft; benzoic acid and 1,2,4-trichlorobenzene detected (27 and 25 ug/kg, respectively) at location SB15 at a depth of 1.5 ft; and pentachlorophenol, detected (200 ug/kg) at location SB02 at a depth of 15 ft. As described for groundwater contaminants, the phthalate compounds which were selected as chemicals of potential concern may also represent sample artifact in soil samples, because they very commonly identified laboratory or field contaminants.

To assess the possibility of elevated levels of inorganic constituents, sample analytical results were compared with results from background locations (Table 7-3). Analytes which appeared elevated were selected as chemicals of potential concern. Chromium, copper, zinc, and cyanide appeared to be elevated at some locations at the Kirsch Co. property above background and were considered chemicals of potential concern. Lead appeared to possibly be elevated at one location at the Wade Electric Co. property. Other inorganic analytes (barium, arsenic, cadmium, cobalt, lead, and nickel) were detected at concentrations above background concentrations in several samples. The

concentrations of these constituents were generally less than two times the background level. Thus, because these metals were not frequently or substantially elevated above background, they were not considered chemicals of potential concern.

#### Analytes Identified in Surface Soils

Analytes detected in surface soils were evaluated in a manner similar to those detected in subsurface soils. All volatile and semivolatile organic compounds detected, other than acetone, chloroform and toluene which were considered to be sample contamination, were considered to be chemicals of potential concern. The pesticides, beta-BHC, dieldrin and 4,4-DDT were not selected as chemicals of potential concern, because they were each identified at only one location. The cyanide and copper concentrations in surface samples at the Kirsch Co. property appeared to be elevated above background levels. These inorganic analytes were selected as chemicals of potential concern, because they were also elevated in subsurface soils.

#### Tentatively Identified Compounds

Numerous tentatively identified compounds (TICs) were also identified in the organic fraction of groundwater and soil samples. Many of these were classified as unknown compounds. TICs were not carried through the risk assessment as chemicals of potential concern, because information on the potential toxicity of these compounds is not available to allow quantification of health risk. This deficiency provides a source of uncertainty which may lead to an underrepresentation of Site risk.

Analytes selected as chemicals of potential concern are further evaluated in the risk assessment. Of these chemicals, those which have available toxicity information will be evaluated in a quantitative manner for their potential to pose human health risks.

## **10.2 EXPOSURE ASSESSMENT**

An exposure assessment is performed to identify actual and potential pathways by which human exposure to contaminated Site media may occur. The assessment considers factors such as the physical location of contaminated areas, the type of contamination and the populations which may come into contact with these areas. Exposure pathways are identified for two Site land use scenarios, pathways based on land use practices as they currently exist, and potential pathways based on land use changes which may occur in the future and result in additional types of exposure.

Both current and future pathways which represent possible exposures are then quantified to estimate the magnitude of daily contaminant exposure a population may incur. To accomplish this, assumptions pertaining to the exposed population are made, such as the nature of the individuals (e.g., child vs. adult), the rate of contact with the contaminated medium (e.g., adult consumes 2 liters water daily) and the length of time the exposure is likely to occur (e.g., years vs. lifetime). These population variables are then compared with chemical concentration data to calculate a level of exposure.

### **10.2.1 Exposure Setting**

Site contamination may generally be described as a contaminated aquifer which has resulted from releases of primarily chlorinated solvents, occurring from at least three identified source areas. The lateral extent of groundwater contamination is controlled by pumping of industrial and municipal water supply wells which surpass the influence of natural groundwater flow gradients. The zone of contamination is currently confined to the central area of the City of Sturgis. The source areas, Kirsch Co. Plant No. 1, Wade Electric Co. and Telemark Business Forms, are characterized by contaminated subsurface soils. Soils at the surface of these areas show minimal contamination. A detailed discussion of the magnitude and extent of Site contamination is presented in the RI Report.

The City of Sturgis encompasses approximately 5 square miles and is comprised of approximately 10,000 residents. The City's economic base is largely industrial with industrial firms generally located along the railroad corridors which traverse the City in east/west and north/south directions. Non-industrial portions of the City consists of commercial and residential areas.

A description of the topography, hydrogeology, and climatology of the region is presented in Section 4 of the RI Report.

#### 10.2.2 Exposure Pathways Based on Current Site Conditions

An evaluation of exposure pathways based on current Site land use is summarized in Table 3. The following discusses potential exposure through specific environmental media.

##### Exposure through Groundwater Use

The City of Sturgis relies solely on groundwater as a source for the municipal water supply system. The municipal system supplies water to the residents of the City proper, as well as customers in adjoining townships. Based on billing records dated June 9, 1990, the municipal system serves a total of 3,894 customers which are comprised of 3,107 residential, 497 commercial, 209 rural, and 81 industrial users. The City water supply system consists of five active wells (PW2-PW6). Supply well PW1 was abandoned by the City between 1985 and 1986. The locations of these wells are shown in Drawing 12686-B1.

Analysis of groundwater samples from the municipal wells conducted during the RI indicates that wells PW2, PW3, and PW4 are contaminated with low levels of TCE (3.0 ug/L or less). Wells PW2 and PW4 showed detectable levels of TCE in only the most recent round of analysis (August 1989).

The demand for municipal water is currently being met through the use of wells PW4, PW5, and PW6. The pumping of two of these wells at a given time is sufficient to maintain an adequate supply in the system. The City currently alternates pumping between two of the three wells on a daily basis, leaving one well inactive. Water from the wells is chlorinated and fluorinated at the well head and pumped directly into the

distribution system. Excess water in the system is stored in a supply tank located near well PW2. Wells PW2 and PW3 currently serve as backup wells to the system. Discussions with the City Water System Supervisor indicated that the backup wells are used infrequently for short periods of time, only to check that the pumps are operating properly. Even during periods of peak demand (i.e., summer months), current pumping practices are capable of maintaining an adequate water supply. Use of wells PW2 and PW3 for municipal water supply needs has not been necessary for the past two years.

Of the water supply wells currently utilized by the municipality, only well PW4 has shown a detectable level of contamination. Actual levels of contamination have not been measured directly at points within the distribution system; therefore, the level of contamination actually reaching the users is not known. It may be surmised that, because of the mixing of water from noncontaminated wells PW5 and PW6 within the system, the concentration of TCE reaching users is less than the 1.0 ug/L level detected at well PW4. However, depending on the structure of the distribution system, some residents may receive water from predominantly one supply well over another. Therefore, the potential health risks associated with residents utilizing water containing contaminant concentrations equal to those at well PW4 were considered applicable under current Site conditions and quantitatively assessed.

To evaluate the possibility that direct use of groundwater may be occurring at the Site, the City Engineering Department was contacted to determine the existence and usage of private wells within the area. Although records of this nature are not readily available or complete, currently utilized private wells appear to be limited to several industrial wells (Ross Co. and Kirsch Co.) within the City. City personnel were not aware of the existence of additional private wells within the City of Sturgis proper, with the exception of three newly installed residential wells (1990) located in the southeast portion of the City, south of Grand Street and east of Independence Avenue. The permitting of these new wells required the approval of the County Health Department, which has knowledge of the groundwater contamination. These wells are located to the southeast of the groundwater contaminant plume.

Ross Laboratories Inc. owns 5 water supply wells (Wells R1-R5). Four of these wells (R1-R4) are located at or near the production facility. Well R5 is located approximately one-half mile to the northeast of this location (see Drawing 12686-B1). Water usage at Ross Laboratories Inc. includes water necessary for product manufacture and water required for equipment cooling. Water used in the production process is supplied from well R5 (water from this well also supplies drinking water to the plant). Organic contaminants have not been identified in groundwater from this location. Even though well R5 is not drawing from the region of the aquifer contaminated by chlorinated ethenes, water utilized in production is treated by passing it through two activated carbon columns. Further, periodic testing of product water for TCE and PCE by Ross Laboratories, Inc. has not shown detectable levels. The remaining wells are used to supply cooling water, with wells R1 and R3 serving typical needs and well R-2 used as a backup. Well R4 is currently not in use.

Three private water supply wells are owned by the Kirsch Co.; two located at Plant No. 1 and one located at Plant No. 2. These wells are currently used only for fire fighting.

City personnel also indicated the existence of approximately 15 private residential wells located on Tracy Drive in the Township of Sherman. These wells are within the bounds of municipal distribution system and are not likely utilized for potable water. The current status or usage of these wells, however, was not determined. Nonetheless, these wells are located north of the plume of groundwater contamination and would not draw from the contaminated aquifer.

Based on current Site conditions and available information on the existence and usage of private wells, it appears that private well owners are not utilizing groundwater from within the identified contaminated plume for potable purposes. Likewise, the industrial use of water for purposes which could lead to human exposure is from an uncontaminated portion of the aquifer. The potential for groundwater contaminants to migrate to private wells will be considered in the discussion of future Site conditions.

### Exposure through Soil Contact

Subsurface and surface soils from potential source areas were collected for contaminant analysis. The results of subsurface soil analyses (Table 10-1) indicated the presence of contamination at the three source areas, with substantial levels occurring at the Kirsch Co. property (260 mg/kg PCE). Lower levels of chlorinated solvents (630 ug/kg or less) were identified at the Wade Electric Co., and Telemark Business Forms Co. properties. Surface soil samples from the Kirsch Co. Plant No. 1, Wade Electric Co., and Telemark Business Forms Co. properties were found to be contaminated with low levels of chlorinated organic solvents, less than 15 ug/kg (Table 10-1).

Each of the source areas are open, flat parcels adjacent to facility buildings and were vegetated with either grass or weeds. Vegetation at the Kirsch Co. property is a thick grass lawn. The Wade Electric Co. and Telemark Business Forms Co. properties are more sparsely vegetated. Property in the immediate vicinity of each source area is developed for commercial or industrial use, however, residential neighborhoods are also in close proximity. Access to the Kirsch Co. property is restricted on the north, south, and east sides by fencing and existing buildings. Access to the property from the western boundary, along Prospect Street, is not limited. Access to source areas at the Wade Electric Co. and Telemark Business Forms Co. is not restricted.

The potential for exposure to contaminated soils under current Site conditions is plausible only for soils located at the surface. Contact with soils below ground surface would require excavation (digging) and is not likely to occur on a regular basis. The most plausible population of individuals which may contact surface soils at these areas is considered to be neighborhood children who may play on these properties. Evidence of playing activity was not noted on these properties during a Site visit. However, a pathway was noted on the Wade Electrical Co. property, indicating that people regularly travel across this area.

To assess potential health risks associated with contacting contaminated soils, contaminant exposure was quantified for children regularly playing in each of the source areas, assuming contact with surface soils. Risks associated with subsurface soils were

considered more plausible if these sources area were developed by construction of a residence in the future. This possibility will be addressed in a later section of this report.

#### Exposure through Ambient Air

Some level of volatilization of contaminants from soils in the source areas to ambient air may be occurring under current Site conditions, based on the volatility of chlorinated organic solvents. Soil gas samples were collected and analyzed for VOC concentrations at the three source areas. Very few VOCs were detected in soil gas, and their concentrations were low. Although ambient air sampling and analysis was not performed as part of RI activities, photoionization detector measurements, employed to screen soil and water samples during well installation, did not identify detectable VOC levels in ambient air (detection limit approximately 1 ppm). This would be expected based on the low concentrations of VOCs in soil pore gas.

To obtain a "worst case" estimate of the possible chemical concentrations in ambient air which may result from the release of volatile chemicals from soils to air, emissions from each of the three source areas were modeled. The VOC soil gas concentrations were used in the emissions rate equation to predict the magnitude of VOC emissions from soils for each source area. The equations used to estimate chemical emission rates are based on steady state diffusion through the soil pore spaces and incorporates "worst case" assumptions including:

- A completely dry soil (moisture dramatically reduces vapor injection in soil);
- No chemical adsorption to soil particles;
- No biodegradation of chemicals; and
- Chemical concentrations in soil remain constant and are not depleted.

The atmospheric fate of chemicals released from the soils were then evaluated by applying an air dispersion model. Volatile chemical concentrations in air were estimated for a distance of 100 m from each source and served as exposure point concentrations. The equations used to estimate chemical emission rates and dispersion of airborne chemicals were obtained from the U.S. EPA Superfund Exposure Assessment Manual, 1988 (SEAM), and are summarized in Table 10-4. Table 10-4 also includes Site-specific assumptions and exposure point concentrations for ambient air.



### Exposure through Surface Water and Sediment Contact

Natural surface water bodies are not present within the City of Sturgis and thus, migration of Site contaminants to these areas (and corresponding exposure) is not applicable. The only surface water body present within the City is an absorption pond, operated by Sturgis Foundry. Contaminated groundwater does not discharge to this pond. Other surface water bodies are present in the vicinity of the City and include the Fawn River to the southeast and south, the Nye Drain to the south, and two chains of lakes to the northwest and northeast. These surface water bodies appear to act as groundwater discharge areas, for groundwater contained in the higher topographic areas between them, including the City. Contaminated groundwater however, is currently confined to the City as a result of the influence of well pumping.

### 10.2.3 Exposure Pathways Based on Potential Future Site Conditions

Changes in Site land use conditions in the future may result in additional types of exposure. An evaluation of exposure pathways based on potential future land use changes is summarized in Table 10-3 and discussed below.

### Exposure through Groundwater Use

Sections 8 and 9 of the RI Report discuss the fate and transport of groundwater contaminants and the results of computer modeling performed to characterize important groundwater flow controlling factors. The lateral extent of groundwater contamination in the future will be dependent on the future utilization of groundwater by the City and industries within the City. Alterations in pumping rates, installation of new production wells, and discontinuation of currently active wells are factors which would influence the migration of groundwater contaminants. Therefore, it is possible that groundwater contaminants may migrate to currently non-contaminated municipal or private potable water supply wells if changes in current pumping practices occur.

The presence of a municipal water system makes it unlikely that a private potable well will be installed within the limits of the system in the future. A permit to install a residential well has, however, recently been granted following approval by the County

Health Department. Although unlikely, in absence of institutional controls (e.g., permitting), a potable water supply well may be installed within the zone of contamination in the future.

To address these two potential means of exposure to contaminated groundwater in the future, potential health risks were estimated for individuals utilizing contaminated groundwater by assuming a potable water supply well would be installed in the future and capable of drawing water from any point in the aquifer.

#### Exposure through Soil Contact

Potential exposure through contacting contaminated surface soils is addressed as part of exposure occurring under current land use conditions. If land use changes do not occur in the future, this potential pathway would likely be similar in the future to that described for current conditions.

A possible land use change which would affect the source areas is development of the properties. Current zoning of the source area properties includes highway - business (Wade Electric Co.), manufacturing (Telemark Business Forms), and apartment dwellings (Kirsch Co. Plant No. 1). Therefore, residential development of the Kirsch Co. property is a realistic possibility. Based on the close proximity of residential neighborhoods to the Wade Electric Co. and Telemark Business Forms parcels, it is conceivable that these areas may also be developed for residential purposes.

To assess the potential health risk associated with contaminated soils, it was assumed that a residence would be constructed at each of the source areas and a hypothetical resident would be exposed to soils for a lifetime. It was further assumed that, through the course of Site development, contaminated subsurface soils would be mixed with surface soils and made available for contact by the residents. The highest contaminant concentration from either subsurface soil or surface soil samples was used to quantify health risk for this exposure scenario.

#### Exposure through Ambient Air

If source soils are not disturbed in the future, the potential for exposure to volatilized contaminants would be as described under current Site conditions. Disturbance of these areas in the future (e.g., Site development) may result in placement of more contaminated soils at the surface. This could result in a short-term increased release of contaminants to air, compared to existing conditions, as contaminants near the surface volatilize.

#### Exposure through Surface Water and Sediment Contact

Exposure through these media are not applicable under current Site conditions, as previously described. In the absence of pumping of municipal and industrial wells, groundwater flow would be controlled by natural conditions and may result in eventual discharge to surface waters in the vicinity of the City (described under current conditions). This possibility is improbable since the City is dependent on groundwater for its water source.

#### 10.2.4 Quantification of Human Exposure Estimates

Levels of exposure are quantified to allow comparison with exposure levels corresponding to adverse health effects. Estimates of contaminant exposure can be derived using the following generic equation:

$$\text{Contaminant Dose Estimate} = \text{Chemical Concentration} \times \frac{\text{Contact Rate} \times \text{Exposure Frequency and Duration}}{\text{Body Weight}} \times \frac{1}{\text{Averaging Time}}$$

The variables in this equation are generally not known with certainty and must be estimated. Variable estimates in this assessment were selected consistent with the State of Michigan and U.S. EPA risk assessment guidelines (MCEQ, 1990 and EPA, 1989a) and are intended to represent maximum exposure estimates which may "reasonably" be expected to be incurred by the exposed population at the Site.

The contaminant dose estimate is expressed in units of mg of contaminant per kg body weight per day and may represent either an "administered" or "absorbed" dose. An administered dose refers to a contaminant exposure which occurs at an exchange boundary of an organism. For example, exposure via ingestion (drinking groundwater) is based on delivery of the contaminant to the exchange boundary which, in this case, is the gastrointestinal tract. Equations which estimate doses for some exposures incorporate a variable which accounts for absorption of the contaminant across the exchange boundary into the blood stream. This estimate is referred to as an absorbed dose estimate. The distinction between administered and absorbed dose estimates is necessary for proper comparison with toxicity information, as is further described in the Toxicity Assessment.

#### Exposure-Point Concentrations

U.S. EPA guidance recommends that the concentration of contaminant in a given medium (groundwater, soil, etc.) used to represent the exposure-point concentration be derived by calculating the 95% upper confidence limit on the mean of sample concentrations (95% UCLM). If this value exceeds the maximum value identified, the maximum value is to be used instead. In the present assessment, 95% UCLM values were calculated for the most frequently identified contaminants in groundwater, TCE and PCE. These 95% UCLM values were greater than the maximum concentrations identified for these compounds and is due to the large degree of variability within the contaminant concentration data. Therefore, maximum contaminant concentrations were used to represent exposure-point concentrations for these data, as well as for all contaminant concentrations in other media.

#### Human Exposure Variables

The contact rate, exposure frequency, exposure duration, and body weight are variables which describe the exposed population and its interaction with Site contaminants. The contact rate refers to the level of exposure to a contaminated medium per unit time (day) or per exposure event. For example, consumption of 2 liters of water per day represents an assumed contact rate for water use. The contact rate is then multiplied by the exposure frequency (events/year) and the exposure duration (years exposure is likely to occur) to arrive at an estimate of the total mass of contaminant the individual is exposed

to through a particular pathway. To allow comparison with toxicity information (usually generated in laboratory animals), the mass of contaminant is expressed on a body weight basis. Values selected for the human exposure variables are based on standard risk assessment assumptions and were obtained from the Draft State of Michigan Risk Assessment Guidelines (MCEQ, 1990) and U.S. EPA Risk Assessment Guidance for Superfund, Volume 1 (1989a). In some cases, plausible assumptions for values are used where standard assumptions are not available (e.g., frequency of children playing in source areas). Human exposure values used in the present assessment are summarized in Table 10-5.

A final term in the dose estimate equation is averaging time, which normalizes the dose over a specified period of time. For chemicals which are potential carcinogens, dose estimates are normalized over a 70-year lifetime to allow comparison with toxicology information generated from studies in test species is exposed to the chemical over the majority of its lifetime. Dose estimates which are used to assess the non-cancer effects of chemicals are normalized over the period of exposure.

#### Routes of Exposure

An exposure route refers to the means by which a contaminant is absorbed into the body. (This is distinguished from an exposure pathway which refers to contact of a specified population with the environmental medium.) Two primary routes of exposure include ingestion with absorption through the gastrointestinal tract, and absorption through the skin (dermal absorption). These two routes of exposure are evaluated in the present assessment for populations exposed to both contaminated soils and groundwater. In addition, exposure to airborne chemicals is evaluated via the inhalation route of exposure (Table 10-5).

#### 10.2.5 Exposure Assessment Summary

Potential exposure pathways were evaluated based on land use conditions as they exist at present and based on assumptions of plausible land use changes which may present additional types of exposures.

Pathways considered to be most significant at the Site include exposure through groundwater use and direct contact with soils, summarized as follows:

#### Current Land Use Conditions

- Exposure of City residents to contaminated municipal water by drinking and through dermal absorption while bathing.
- Exposure of children to contaminated surface soils through incidental ingestion and dermal absorption while playing in source areas.
- Exposure of City residents to volatile contaminants in ambient air released from soils.

#### Potential Future Land Use Conditions

- Exposure of future residents to contaminated groundwater resulting from either installation of a well within the contaminant plume or by migration of groundwater contaminants to existing wells. Exposure may occur through drinking and dermal absorption. Contaminant concentrations are assumed to exist in the future as under current conditions.
- Exposure of individuals to contaminated soils at a future residence developed at the source areas. Exposures may occur through incidental ingestion of soil and dermal absorption. It is assumed contaminants in either surface or subsurface soils at current concentrations are made available for exposure as a result of Site development.

### 10.3 TOXICITY ASSESSMENT

This section addresses the nature of the toxic effects which may result from exposure to the chemicals of potential concern. The risk assessment addresses two general types of toxicities which may result from chemical exposure; cancer and non-cancer effects. Because these two broad types of toxicity are assumed to be expressed through different biological mechanisms, the methods used to quantify these effects are different. These are described below.

#### 10.3.1 Dose - Response Relationship

The type, severity, and frequency of occurrence of a given toxic effect observed within a population (response) is a function of the magnitude of chemical exposure (dose). Different chemicals which produce similar toxicities within a species usually do so at different concentrations (i.e., have different toxic potencies). These relative differences

in the dose-response relationships among chemicals are addressed in the risk assessment by considering "critical toxicity values" developed by the U.S. EPA. Critical toxicity values have been derived for potential noncarcinogenic effects and potential carcinogenic effects of the chemicals and are termed reference doses (RFDs) and slope factors (SFs), respectively.

#### Non-cancer Effects

Non-cancer effects include any toxicity other than cancer. These effects are often categorized by the particular organ which is affected, for example, liver or kidney toxicity. Because the tissues are generally capable of tolerating some level of chemical exposure, chemicals causing non-cancer effects are assumed to display a threshold phenomenon; i.e., effects are not observed below a given chemical concentration (threshold dose). Therefore, a health risk is thought to exist only if established threshold doses are exceeded.

The non-carcinogenic dose-response relationship is addressed in the toxicity assessment by considering RFDs, expressed in mg contaminant/kg body weight/day, which are levels of contaminants not expected to cause adverse health effects in humans, including sensitive subsets of the population. RFDs are generally estimated from No-Observed Adverse Effect Levels (NOAELS), determined from animal studies, which are the highest chemical concentrations which produce no adverse effects. Safety factors related to various assumptions made (e.g., animal to human extrapolation) are incorporated in the derivation of the values to result in a more health-protective estimation.

#### Carcinogenic Effects

In the present risk assessment, all carcinogens (cancer-causing agents) are considered to have a dose-response relationship with no threshold. Theoretically, any exposure to a carcinogen is associated with some degree of risk for developing cancer.

The cancer potentials of carcinogens are known with varying degrees of certainty, depending on the amount and quality of scientific information available. The U.S. EPA has developed a system to review this information and to classify chemicals as to their likelihood of causing cancer. For example, this classification scheme distinguishes between chemicals which are known human carcinogens (Group A), and chemicals which are probable human carcinogens (Group B), based on their cancer causing properties in animal studies. The dose-response relationship for an established or potential carcinogen is incorporated into the SF; a value expressed in  $(\text{mg/kg-d})^{-1}$  which is directly proportional to the cancer potency of the chemical.

#### 10.3.2 Critical Toxicity Values

The critical toxicity values (RFDs and SFs) used in the present risk assessment are shown in Table 10-6. These values were obtained from U.S. EPA's IRIS toxicology information database (EPA 1990b) and the U.S. EPA's Health Effects Assessment Summary Tables (EPA 1990a).

Toxicity values are generally based on the level of a chemical "administered" to a test animal. This situation does not account for the ability of the animal to absorb the compound into the blood stream. Toxicity values can be adjusted to account for this factor by incorporating an estimate of the level of absorption which is likely to occur. In the present risk assessment, toxicity values based on "administered" doses were adjusted to an "absorbed" dose basis to allow proper comparison with estimates of human exposure, which represent either an administered or an absorbed dose (Section 3.0). Absorption estimates and critical toxicity values, presented in Table 10-6, were derived in accordance with U.S. EPA Risk Assessment Guidelines (EPA, 1989a).

Toxicity values are based on a "critical" toxic effect in an animal. These are generally the most sensitive effects observed (those detected at lowest doses). The critical effect for the chemicals of potential concern are listed in Tables 10-7 through 10-11, which also summarize estimated health risks.



The lack of appropriate toxicological information to date limits the derivation of toxicity values for some of the chemicals. In these cases, the potential health risk to these compounds can not be quantified and will be discussed in only a qualitative way.

#### 10.4 RISK CHARACTERIZATION

In this section, estimates of contaminant exposure are compared with toxicity information to arrive at an estimate of potential human health risk. Two general types of toxicity endpoints are evaluated for chemicals of potential concern in this assessment, i.e., cancer and non-cancer effects. Because the assumptions related to how chemicals produce cancer and non-cancer toxicities differ, the methods employed to qualify these risks also differ. These are described below. In addition, in this section, potential health risks associated with exposures evaluated under current and future land use conditions will be described.

##### 10.4.1 Procedures Used to Quantify Health Risk

###### Non-Cancer Effects

Estimating the risk of a non-cancer health effect is accomplished by calculating a hazard quotient. The hazard quotient for a chemical is calculated by dividing the human contaminant dose estimate by the Reference Dose for the chemical as shown below. Dose estimates which represent administered doses are compared with RFDs based on administered doses and absorbed dose estimates are compared with similarly derived RFDs.

$$\text{Hazard Quotient} = \frac{\text{Contaminant Dose Estimate (mg/kg-d)}}{\text{Reference Dose (mg/kg-d)}}$$

For a given exposure pathway, the hazard quotients for all chemicals of potential concern are added to arrive at a total. This value is referred to as the hazard index (HI) for the exposure pathway. If the HI (or hazard quotient) exceeds unity (1), there may be a potential health risk associated with exposure via the particular pathway (or chemical) evaluated.

### Carcinogenic Effects

The risk of developing cancer from chemical exposure is estimated by multiplying the estimated contaminant dose by the slope factor for the chemical as shown below. Dose estimates which represent administered doses are compared with SFs based on administered doses and absorbed dose estimates are compared to similarly derived SFs.

$$\text{Cancer Risk} = \frac{\text{Contaminant Dose Estimate (mg/kg-d)}}{\text{Slope Factor (kg-d/mg)}}$$

As with non-cancer hazard quotients, the cancer risks associated with specific chemicals within an exposure pathway are assumed to be additive, and summed to arrive at a total exposure pathway cancer risk.

The cancer risk value is an estimate of an individuals' lifetime likelihood of developing cancer over and above the existing background chance of developing cancer. A cancer risk of  $1 \times 10^{-6}$ , for example, may be interpreted as an increased risk of one in one million of developing cancer over a person's lifetime. This risk may also be interpreted on a population basis, to predict that one additional case of cancer may occur in a population of one million exposed people.

#### 10.4.2 EPA Health Risk Goals

The U.S. EPA has developed program goals pertaining to potential health risks estimated from exposure to contaminants at Superfund Sites. For chemicals which may cause non-cancer effects, acceptable exposure levels are intended to represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety (i.e., an HI of less than 1). For known or suspected carcinogens the  $1 \times 10^{-6}$  risk level is used by U.S. EPA as a "point of departure" for determining remediation goals. Risks below this level are not considered to be of concern. Cancer risks which are between  $1 \times 10^{-6}$  and  $1 \times 10^{-4}$  may or may not be acceptable, depending on other risk management factors (e.g., nature of exposure, efficacy of treatment technologies, cost, and others) applicable to the Site.

#### 10.4.3 Public Health Evaluation

Potential health risks were evaluated for contaminant exposures based on two land use scenarios; current Site conditions and possible future Site conditions. As part of these evaluations, risks to groundwater, subsurface soil, and surface soils were assessed. These are described below and summarized in Tables 10-7 through 10-11.

#### Potential Risks Based on Current Land Use

Current health risks associated with groundwater use were evaluated for residents utilizing municipal water and water from private wells. Based on the location of identified residential wells, exposure to contaminated groundwater (and corresponding risk) is not occurring, because these wells do not draw from the zone of contaminated groundwater. Likewise, currently existing industrial wells which use water for human consumption (well R-5, Ross Laboratories Inc.) is not located within the zone of contamination. Other wells utilized by Ross Laboratories Inc. have shown to be contaminated with chlorinated ethenes. However, these wells are used for cooling water which does not result in exposure.

Municipal well PW4 was found to contain 1.0 ug/L TCE in the most recent round of groundwater sampling. This well, in addition to wells PW5 and PW6, is currently utilized to supply municipal water. Other contaminants identified in these municipal wells included low levels of chloroform and BEHP. To evaluate potential health risk to residents utilizing municipal water, it was assumed that residents could be exposed to the maximum contaminant concentration in any of the currently utilized municipal wells. Risks were evaluated for both exposure via ingestion and dermal absorption of contaminants. Potential risks to non-cancer health effects were below a level of concern as indicated by an exposure pathway HI of 0.01 (Table 10-7). Cancer risks associated with this pathway were slightly above the level considered by U.S. EPA to be of concern ( $3 \times 10^{-6}$  compared to the  $1 \times 10^{-6}$  point of departure, Table 10-8). However, this risk was primarily related to exposure to BEHP, which may be a sample contaminant and not actually related to groundwater quality. The cancer risk associated with TCE was not at a level of concern ( $3 \times 10^{-7}$ ). In addition, the cancer risk associated with chloroform,

possibly related to chlorination of municipal water, was comparable to that of TCE.

The most realistic exposures to contaminated soils under current land use conditions were considered to be to children playing in the source areas and contacting surface soils directly. Exposure to soil in subsurface locations was not considered likely at present. To assess potential risks to contaminants in surface soils, children were assumed to play in these areas and be exposed through incidental ingestion of soil and dermal contact. Each of the three source areas was considered separately in this assessment. Potential risks to the non-cancer effects of contaminants were below a level of concern for each of the source areas, as the exposure pathway hazard indices were less than one (Table 10-7). Estimated cancer risks (Table 10-8) were greater than the  $1 \times 10^{-6}$  U.S. EPA point of departure for both the Kirsch property ( $2 \times 10^{-5}$ ) and the Wade Electric Co. property ( $2 \times 10^{-6}$ ). These risks were related nearly entirely to the presence of PAHs at both locations. Cancer risks at the Telemark Business Forms property were substantially less than  $1 \times 10^{-6}$  ( $2 \times 10^{-10}$ ).

The presence of volatile chemicals in the soils at the three properties suggests that contaminants may be released to the atmosphere and present a pathway for human exposure. To evaluate this possibility chemical emission rates were estimated and downwind air concentrations of contaminants were calculated (Table 10-4). Potential health risks associated with this exposure pathway are presented in Table 10-9.

Potential non-cancer health hazards associated with each of the source areas are not anticipated to be of concern as the pathway hazard index for each was less than 1.0. The potential cancer risk was estimated to be above the U.S. EPA's point of departure for the Kirsch property ( $7 \times 10^{-6}$ ). The cancer risk estimates for the Wade Electric property ( $1 \times 10^{-7}$ ) and Telemark Business Forms property ( $4 \times 10^{-10}$ ) were substantially below the U.S. EPA's point of departure. It should be noted that the equations used to derive these numbers incorporated many "worst case" assumptions which would result in values very likely much higher than what would actually be expected.

### Potential Risks Based on Possible Future Land Use

Groundwater utilization practices within the City of Sturgis in the future could result in the migration of groundwater contaminants to uncontaminated municipal and residential wells. In addition, it is conceivable that in the absence of institutional controls (e.g., permitting through the County Health Department), a private residential well could be installed within the zone of groundwater contamination. To address these potential land use changes, it was assumed that contaminated groundwater would be utilized in the future and exposure would occur through ingestion and dermal absorption. It was further assumed that contaminant concentrations would exist as they do currently and that water could be drawn from any point in the contaminated aquifer.

Potential health hazards from the non-cancer effects of the contaminants may be of concern under these assumptions as evidenced by a HI of 1.0 (Table 10-10). The contaminants contributing most to this health hazards are PCE and cyanide, although individually, the hazard quotients for these compounds were less than 1.0. Cancer risks for the combined exposure to all chemicals of potential concern in groundwater exceeded U.S. EPA's acceptable range (total pathway risk  $6 \times 10^{-3}$ ). The majority of this risk was related to exposure to TCE (Table 10-11).

As with groundwater exposure, future land use changes could present an increased exposure to contaminated soils. Each of the source areas are in close proximity to residential neighborhoods. On this basis, it is conceivable that future development of properties containing the source areas may include the construction of a residence. To assess the potential health risks associated with exposure to contaminated soils, it was assumed that, in the course of development, soils at any depth could be brought to the surface and made available for contact with a future resident. This hypothetical resident was assumed to reside at this location his entire life and be exposed to soils via incidental ingestion and dermal contact. These assumptions were applied to soils in all three source areas.

The potential health hazards to non-cancer effects, as measured by the HI, were below a level of concern (i.e., 1.0) for each of the source areas (Table 10-10). Contaminated soils at the Kirsch Co. property had the highest HI of the three source areas (0.3). Estimated cancer risks for the Kirsch Co. and Wade Electric Co. properties were above the U.S. EPA  $1 \times 10^{-6}$  point of departure level;  $5 \times 10^{-4}$  and  $7 \times 10^{-5}$ , respectively (Table 10-11). In both cases, these risks were associated with contact with carcinogenic PAHs. Since PAHs are not constituents of halogenated organic solvents, their presence at these areas is related to chemical releases of another type (possibly petroleum fuels). Total exposure pathway cancer risks estimated at the Telemark Business Forms property were below a significant level ( $3 \times 10^{-8}$ ).

#### 10.4.4 Uncertainties in the Risk Assessment Process

The risk assessment process incorporates numerous assumptions and is associated with a great deal of uncertainty. Thus, calculated risk estimates are not to be construed to necessarily represent actual risks. Proper interpretation of health risk values requires consideration of the uncertainties and assumptions involved in the risk calculations.

Assumptions are applied in each step of the process, including Site contaminant characterization, exposure assessment, toxicity assessment, and risk characterization. These assumptions may underestimate risks or overestimate risks. Examples of some key uncertainty factors and assumptions applied in the risk assessment are described below, as well as indications of their biases:

- Assume Site is fully characterized. The presence of areas of contamination not identified may result in an under estimation of Site risks.
- Assume identified chemicals are associated with the majority of Site health risk. The presence of highly toxic compounds not analyzed for or identified compounds for which little toxicity information exists may result in an underestimation of Site risks.
- Exposure concentrations of contaminants are derived using conservative assumptions likely overestimating actual levels and thus, risk. For example, air contaminant concentrations were derived using "worst case" assumptions.

- Exposure assumptions are conservative and likely overestimate risk. For example, estimates of soil exposure for future residents assume lifetime occupancy at the residence.
- Toxicity values may overestimate risk. Reference doses incorporate conservative uncertainty factors and cancer slope factors estimate upper bound 95th percentile values.
- Evaluating potential future risks (e.g., future residents and private well users) without consideration of the likelihood with which these scenarios may occur overestimates actual risk.

### 10.5 ENVIRONMENTAL ASSESSMENT

The objectives of this component of the Baseline Risk Assessment are characterize the natural habitats which may be influenced by the Site, and to appraise the actual or potential adverse effects contaminants have on these habitats. Relative to the human health assessment, the methodology for an ecological assessment is much less defined. However, the overall approach to the environmental assessment is analogous to that of human health assessments, and includes identifying contaminants of potential concern, pathways of contamination migration, and populations (flora and fauna) potentially affected by Site contamination. To the extent possible, actual adverse impacts to natural habitats are determined. Similarly, the potential for future environmental impact is also described.

The identified sources of contamination at the Site are within the City of Sturgis. These areas are located adjacent to industrial or commercial enterprises and do not constitute valuable ecological habitats. At present, the plume of contaminated groundwaters is confined to the City as a result of current water use practices. Discharge of contaminated groundwater to surface water bodies is also not occurring. If a change in water utilization practices would occur in the future, such that the natural flow gradient would control groundwater movement, contaminated groundwater could be discharged to surface water bodies which are located outside of the City (Section 3.0). If this were to occur, ecological habitats in these areas may be at some risk. However, this scenario appears unlikely, because the City of Sturgis relies on groundwater as it source of water. In addition, the adverse impact of groundwater contaminants on wetland or riverine habitats would be dependent on other factors, including toxicity of the chemical on wildlife, the ultimate chemical concentration in these areas, and the chemicals persistence in the environment.

## **11.0 SUMMARY AND CONCLUSIONS**

The Site RI characterized the geology and groundwater beneath the City, investigated potential sources of contamination to the City's industrial process and municipal water supply wells, and provided the potential extent and migration routes of contamination within the aquifers underlying the City. Little information regarding the geology or the vertical and horizontal distribution of the groundwater contamination plume or potential source areas was available prior to the RI. Activities conducted during Phase I, II, and IIB of the RI consisted of:

- An industrial survey;
- Soil gas surveys and 21 soil borings near suspected VOC source areas;
- The installation of 63 new wells;
- Four rounds of groundwater quality sampling;
- Water level measurements;
- Hydraulic conductivity tests; and
- Groundwater flow modeling.

### **11.1 INDUSTRIAL SURVEY**

Several industries were surveyed to determine their general processes and current and past use of chlorinated solvents. The surveys were conducted at United Paper Inc., Walker-Bandholtz Paint Manufacturing Co., Frye Copy Systems, Kirsch Company Division of Cooper Industries, Sturgis Newport Business Forms, Abbott Laboratories Ross Division (Ross Labs), Sturgis Foundry Corporation, and several other small industries. Based on the results of the survey (Appendix B), areas were selected for soil gas surveys to identify potential source areas.

### **11.2 SOIL GAS SURVEY AND FIELD ANALYSIS**

Soil gas surveys were conducted in several potential VOC source areas to identify locations for soil borings and monitoring wells to characterize the potential source areas. To compensate for the initial lack of geologic and geochemical data, the field



investigation relied on sampling and on-Site chemical analysis to allow continual re-evaluation of monitoring well placement. The use of soil gas sampling and analysis was instrumental in selecting potential VOC source areas for further investigation, including Sturgis Newport Business Forms, Telemark Business Forms, Wade Electric, and Kirsch Co.

### **11.3 DRILLING AND GEOLOGY**

Well borings used in conjunction with previously existing well logs show the geology underlying the City. The City overlies an area of complex glacial sediments derived from the Michigan Lobe, the Saginaw Lobe, and the Erie Lobe of the Woodfordian Substage of the Wisconsinian stage of Pleistocene glaciation. Several separate glacial till units and associated sand, gravel, silt, and clay outwash units occur in the subsurface of Sturgis (Drawings 12686-15 through 12686-19). These units unconformably overlie shale bedrock, assumed to be the Mississippian Age Coldwater Shale. An indurated sand and gravel deposit, assumed to be Quaternary Age, forms a thin local deposit between the Coldwater Shale and the overlying glacial deposits.

Three till units were encountered, including a deep till unit, an intermediate depth till unit, and a surficial or near surface till unit, during drilling activities performed for the RI. The till was categorized as an unsorted, massive to crudely stratified sedimentary unit composed of varying amounts of silt, clay, sand and gravel. Each unit was separated by varying thicknesses of outwash deposits (see Appendices C-1 and C-3).

The deep till unit (Table 5-1) observed during drilling activities was encountered at approximately elevation 700 ft MSL. This deep till unit lies unconformably over the Coldwater Shale, is apparently discontinuous, and is assumed to be deposited in either early Woodfordian or Pre-Woodfordian time. The deep till unit is overlain by outwash deposits.

The intermediate till unit (Table 5-1) was encountered between approximate elevations 750 ft and 850 ft MSL at most wells drilled to this depth. Thickness of the intermediate till ranged from 90 ft to non-existent. The majority of this till consists of clay or silt. Textural variations such as these typically reflect different ice lobe depositions within an

area, with the Lake Michigan Lobe and Erie Lobe depositing silt and clay till, and the Saginaw Lobe depositing the sandier till.

Outwash thickness encountered between the intermediate till unit and the near surface till unit varied from 20 ft to 100 ft or more. Proximal and/or medial outwash facies were typical of outwash deposits within this unit (Table 5-1).

#### 11.4 HYDROLOGY AND HYDROGEOLOGY

The City is located in the center of a surface water divide, with the Fawn River to the south, and a chain of lakes and the Prairie River drainage system to the north of the City (Drawing 12686-B1). The Nye Drain, the closest natural surface water feature to the City, is a northeast to southwest flowing stream located within the southern half of the City. The Nye Drain changes from an intermittent to permanent stream at the discharge point from the City sewage treatment plant. The Nye Drain flows to the southwest and discharges to the Fawn River, approximately 2 miles south-southwest of the City.

Water table maps (Drawings 12686-7 through 12686-10) show a cone of depression which has a northwest/southeast orientation. This cone of depression is caused by the absence of till layers and a good hydraulic connection between the lower and upper aquifers. This allows drawdown in the lower aquifer to affect flow in the upper aquifer, such that groundwater moves from the upper aquifer to the lower aquifers through windows in the till units. The depression dominates the flow field in the upper aquifer. The maps also show a groundwater mound occurring in the vicinity of well MW4, probably due to surface water discharge at Sturgis Foundry Corporation, and generally high groundwater elevations occurring at locations where considerable thicknesses of the upper till unit are present.

Potentiometric surface maps (Drawings 12686-11 through 12686-13) show the local groundwater flow direction in the lower aquifer below the City is from northeast to southwest. Pumpage from municipal and industrial wells causes deviation from the local flow direction, and provides the mechanism to produce downward vertical gradients. A relatively flat horizontal gradient is present in the lower aquifer. Widespread pumping effects, combined with high hydraulic conductivity in the lower aquifer, likely produce this effect.

In-situ hydraulic conductivity tests (Table 5-4) were performed in 39 wells and piezometers at the Site. The 80% confidence interval of the conductivity for each permeable unit (upper, middle, and lower outwash deposits) describes the units' variability. It appears that the upper outwash is more permeable than the lower outwash deposits.

#### 11.5 CONTAMINANT CHARACTERIZATION

The primary contaminants found during the RI (Appendix E) are trichloroethene (TCE) and tetrachloroethene (PCE). Contaminants migrated from source areas to deep within the aquifer under the influence of local groundwater pumping. The strong influence of groundwater withdrawal pulls the contamination to the northwest, southwest, and perhaps to the southeast. High levels of contamination ( $> 1000 \mu\text{g/L}$ ) extend through the lower outwash unit up to well R-4, and probably to well PW2 (Drawing 12868-6).

The RI did not find evidence of DNAPLs during the groundwater or soil sampling investigation tasks. The maximum TCE concentration detected was  $20,000 \mu\text{g/L}$ , found during the boring of W26D and W34I. Since these observed concentrations are about 2% of the solubility limit, it is unlikely that DNAPLs are present in the groundwater.

Soil borings and monitoring wells were placed on four potential source areas, based on results of a confidential PRP search conducted by TechLaw, a survey of industries and businesses in Sturgis performed by Warzyn, a survey of waste water discharge conducted by the City of Sturgis Waste Water Treatment Plant, and a soil gas survey performed by Warzyn. These locations included Kirsch Co. Plant No. 1, Wade Electric, Telemark Business Forms and Sturgis Newport Business Forms (Drawing 12686-5). At Kirsch Co. Plant No. 1, soil borings in potential source areas showed elevated VOC levels (up to  $99,000 \mu\text{g/kg}$  TCE and  $260,000 \mu\text{g/kg}$  PCE) in a number of shallow soil samples. Deeper samples showed that the VOCs were present down to the water table. The elevated soil concentrations appear to be limited to the area near SB-06, the railroad spur near W11S, and W42S. These shallow soils are potential sources of continuing groundwater contamination.

Groundwater sampling shows VOC contamination beneath Kirsch Co. Plant No. 1. Wells W32S and W42S contained over 5000 ug/L of chlorinated ethenes. Monitoring from other wells indicate that wells W32S and W42S are near source areas(s).

Downgradient wells W26S and W2D contain higher VOC concentrations than on-Site wells. This suggests that the contaminants have moved downgradient from the source area, and current contaminant release from the source area to the aquifer occurs at a slow rate.

Soil samples were collected from six soil borings at Wade Electric. The highest TCE and PCE concentrations were found in two borings located near former underground storage tanks. The highest concentration of CLP VOCs was present near the former tank at a depth of 4.5 ft (160 ug/kg TCE; 630 ug/kg PCE). The vertical contaminant profile at this location showed a relatively uniform VOC distribution. The bulk of the contamination may have already moved into the aquifer from the source.

The wells installed to investigate the Wade Electric source area confirm the source of contamination to groundwater is likely in the area of the former underground storage tanks. TCE concentrations in this area ranged from 160 to 330 ug/L.

Wells W27S, W27I and W27D were installed to differentiate between the Wade Electric and Kirsch Co. Plant No. 1 plumes. The results from this well suggests that the contamination beneath Wade Electric occurs in the upper aquifer and is not related to the Kirsch Co. Plant No. 1 plume located in the deep aquifer. Contamination from Wade Electric may be moving to the north, west, and south, under the influence of the water supply wells, toward windows in the low permeability till units.

Soil contamination at Telemark Business Forms was characterized from samples obtained from the boring for well W10S. Soil contamination showed very low levels of TCE ( $\leq 2$  ug/kg) and the majority of the PCE contamination was located near the surface (110 ug/kg at level 5 ft; ND at 10 ft).

Groundwater sampling suggests that groundwater impacts from Telemark Business Forms may be localized. Well W10S, located at a probable source area, contained a maximum of 11 ug/L PCE and well W16S (200 ft downgradient) had no detectable levels of PCE. Upgradient wells contained no detectable or low levels (4 ug/L) of TCE, while downgradient wells contained about 10 ug/L.

Soil contamination at Sturgis Newport Business Forms was characterized from samples obtained from the boring for well W9S. Soil contamination was limited to the shallow soils. The 1-ft soil sample contained 1100 ug/kg PCE and no detectable TCE. The 5-ft soil sample had no detectable levels of PCE or TCE. Groundwater sampling of well W9S confirmed that contamination was limited to the shallow soils. No detectable levels of VOCs were found in this well.

The groundwater flow model developed for the area confirmed observations made regarding groundwater flow direction (Drawings 12686-23 and 12686-24). The advective particle tracking model, coupled to the flow model, showed potential travel path directions (Drawing 12686-25) for non-dispersive, non-reactive solutes entering the flow system at discrete locations and time intervals, and helped to reinforce observations regarding the areal and vertical extent of contamination.

#### **11.6 RISK ASSESSMENT**

The purpose of the Baseline Risk Assessment was to characterize the nature and estimate the magnitude of potential health and risks to public health and the environment which may occur due to exposure to contaminants identified at the Site.

Initially, chemicals of potential concern were selected based on their presence in media in comparison to background concentrations of the chemicals. The chemicals of potential concern are summarized in Table 10-2. Next, estimates of exposure to the chemicals in contaminated media were estimated for each source area based on current Site conditions, as well as potential future Site conditions. The following paragraphs describe the pathways of exposure which were considered most significant based on current and potential future land use conditions.

### Current Land Use Conditions

- Exposure of City residents to contaminated municipal water by drinking and through dermal adsorption while bathing.
- Exposure of children to contaminated surface soils through incidental ingestion and dermal adsorption while playing in source areas.
- Exposure of City residents to volatile contaminants in ambient air released from soils.

### Potential Future Land Use Conditions

- Exposure of future residents to contaminated groundwater resulting from either installation of a well within the contaminant plume or by migration of groundwater contaminants to existing wells. Exposure may occur through drinking and dermal absorption. Contamination concentrations are assumed to exist in the future as under current conditions.
- Exposure of individuals to contaminant soils at a future residence developed at the source areas. Exposures may occur through incidental ingestion of soil and dermal adsorption. It is assumed contaminants in either surface or subsurface soils at current concentrations are made available for exposure as a result of Site development.

Finally, estimates of the toxicity of each chemical of potential concern were used in conjunction with the estimates of human chemical exposure to arrive at health risk estimates. Health risks were estimated for both noncancer effects (e.g., liver damage) and cancer effects. Non-cancer effects were estimated by calculating hazard indices (HI), while cancer effects were estimated by calculating probabilities of cancer risk. A HI value less than one indicates that exposure to the multiple chemicals at the Site is not expected to cause non-cancer effects in the exposed population. The cancer risk estimates are compared to the U.S. EPAs risk range of  $1 \times 10^{-4}$  to  $1 \times 10^{-6}$ .

The following is a summary of the health risk estimates based on current and future Site conditions, respectively.

### Potential Risks Based on Current Land Use

Current health risk associated with groundwater use were evaluated for residents utilizing municipal water and water from private wells. To evaluate potential health risk to residents utilizing municipal water, it was assumed that residents could be exposed to

the maximum contaminant concentrations in any of the currently utilized municipal wells. Risks were evaluated assuming both ingestion of water and dermal contact while bathing.

Non-cancer health effects would not be expected ( $HI < 1$ ) and the level of cancer risk was slightly above the point of departure ( $3 \times 10^{-6}$  compared to  $1 \times 10^{-6}$ ). This risk, however, was primarily related to BEHP, which may be a sample contaminant and not actually related to groundwater quality. The remainder of the cancer risk was below the point of departure.

The most realistic exposures to contaminated soils under current land use conditions were considered to be to children playing in the source areas and contacting surface soil directly. Three source areas (i.e., Kirsch Co., Wade Electric Co., and Telemark Business Forms) were found to be contaminated during the RI; therefore, health risks for each area were calculated separately.

Noncancer effects would not be expected at any of the three source areas. Cancer risk estimates for both the Kirsch property ( $2 \times 10^{-5}$ ) and Wade Electric Co. property ( $2 \times 10^{-6}$ ) were greater than the point of departure ( $1 \times 10^{-6}$ ). These cancer risks were primarily related to the presence of PAHs at both locations. The cancer risk estimate at the Telemark Business Forms property ( $2 \times 10^{-10}$ ) was substantially less than  $1 \times 10^{-6}$ .

The presence of volatile chemicals in soils at the three properties suggests that contaminants may be released to the air and present an additional pathway for human exposure. Non-cancer health effects via inhalation of volatile chemicals released to ambient air are not expected at any of the three source areas based on HI estimates ( $< 1$ ) at each location. The potential cancer risk associated with inhalation of volatiles at the Kirsch property ( $7 \times 10^{-6}$ ) was above the U.S. EPA's point of departure. The cancer risk estimates for the Wade Electric Co. property ( $1 \times 10^{-7}$ ) and Telemark Business Forms property ( $4 \times 10^{-10}$ ) were substantially below the  $1 \times 10^{-6}$  point of departure.

#### Potential Risk Based on Possible Future Land Use

Groundwater utilization practices within the City of Sturgis in the future could result in the migration of groundwater contaminants to uncontaminated municipal and residential wells. Therefore, health risks were estimated assuming people drink the contaminated water and bathe in it in the future. Non-cancer effects of the contaminants may be of concern as the HI was estimated to be 1.0. The primary chemicals contributing to this HI estimate are PCE and cyanide, although individually, the hazard quotients for these compounds were less than 1.0. Cancer risks for the combined exposure to all chemicals of potential concern in groundwater exceeded the U.S. EPA's acceptable range ( $6 \times 10^{-3}$ ). The majority of this risk was related to TCE exposure.

In the future, it was assumed that a residence may be built at the locations of the three source areas. It was assumed residents may be exposed to subsurface soils that are brought to the surface during construction via incidental ingestion and dermal contact. It was assumed residents were exposed to the soil each day of their lives.

Non-cancer health effects would not be expected for residents at any of the three source areas. The cancer risk estimate for the Kirsch Co. ( $5 \times 10^{-4}$ ) and Wade Electric Co. properties ( $7 \times 10^{-5}$ ) were above the U.S. EPA's point of departure ( $1 \times 10^{-6}$ ). In both cases, the majority of the cancer risk was associated with contact with PAHs. The cancer risk estimate for Telemark Business Forms property ( $3 \times 10^{-8}$ ) was below  $1 \times 10^{-6}$ .

#### Environmental Assessment

The objective of the environmental assessment was to characterize the natural habitats which may be influenced by the Site, and to appraise the actual or potential adverse effects contaminants have on these habitats. Identified contamination is within the City of Sturgis, and in areas not containing sensitive habitats. For this reason, ecological effects are not anticipated.



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Table 2-1

Michigan Department of Public Health  
Municipal Well Sampling Events  
Pre-RI/FS  
Sturgis, Michigan

<u>Sampling Location</u>	<u>Date</u>
Distribution	December 7, 1976
Distribution	July 29, 1979
Distribution	December 7, 1980
Distribution	June 8, 1982
Distribution	August 20, 1982
Jackson	September 29, 1971
Jackson	January 27, 1974
Jackson	June 8, 1982
Jackson	June 26, 1982
Jackson	August 20, 1982
Jackson	September 29, 1982
Jackson	May 28, 1983
Kirsch	September 29, 1971
Kirsch	January 27, 1974
Kirsch	June 8, 1982
Kirsch	June 26, 1982
Kirsch	August 20, 1982
Kirsch	December 8, 1983
Kirsch	January 13, 1985
Kirsch	January 27, 1985
Kirsch	July 10, 1985
Kirsch	May 13, 1986
Lakeview	July 26, 1955
Lakeview	September 29, 1971
Lakeview	January 27, 1974
Lakeview	January 13, 1985
Lakeview	July 10, 1985
Layne	January 27, 1974
Layne	June 8, 1982
Layne	June 26, 1982
Layne	August 20, 1982
Layne	September 29, 1982
Layne	January 9, 1983
Layne	May 28, 1983
Oaklawn	April 3, 1984
Oaklawn	April 6, 1984
Oaklawn	July 10, 1985

TABLE 3-1

Summary of Contract Laboratory Program Analysis of Groundwater Samples (a)  
Sturgis Well Field  
Sturgis, Michigan

Sampling Round:	Volatile Organics				Semi-Volatile Organics, Pesticides/PCBs				Metals				Indicator Parameters				SAS Volatile <sup>b</sup> Organics
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	During Drilling
<u>Well I.D.</u>																	
MW-1A	S	S	S						S	S	S		S	S	S		
MW-1B	S	S	S						S	S	S		S	S	S		
MW-1C	SD	SD	S						SD	SD	S		SD	SD	S		
MW-2B	S	S	S						S	S	S		S	S	S		
MW-2C	S	S	S						S	S	S		S	S	S		
MW-3A	S	S	S						S	S	S		S	S	S		
MW-3C	S	S	S						S	S	S		S	S	S		
MW-4	S	SD	S						S	SD	S		S	SD	S		
MW-6	S	S	S						S	S	S		S	S	S		
GW-1	SD	S	S						SD	S	S		SD	S	S		
GW-2	S	S*	S						S	S	S		S	S	S		
GW-3	S	S	S						S	S	S		S	S	S		
GW-4	S	S							S	S			S	S			
GW-7	S	S, R	S			R			S	S, R	S		S	S	S		
GW-8	S	S	S						S	S	S		S	S	S		
TW-B3A	S	S	S						S	S	S		S	S	S		
TW-B4A	SD	SD	SD						SD	SD	SD		SD	SD	SD		
A-1	S								S				S				
F-1	S	S, R	R*			R	R		S	S, R	S, R		S	S	S		
R-1	S	S	R				R		S	S	S, R		S	S	S		
R-2	S	S	S						S	S	S		S	S	S		
R-3	S	S	S						S	S	S		S	S	S		
R-4	S	S, R	R			R	R		S	S, R	S, R		S	S	S		

TABLE 3-1  
(Continued)

Sampling Round:	Volatile Organics				Semi-Volatile Organics, Pesticides/PCBs				Metals				Indicator Parameters				SAS Volatile Organics
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	During Drilling
<u>Well I.D.</u>																	
R-5	S	S	S						S	S	S		S	S	S		
PW-2	S	SD		S					S	SD			S	SD			
PW-3	SD	S, R	R	S		R	R		SD	S, R	S, R		SD	S	S		
PW-4	S	S, R	RD	S		R	RD		S	S, R	SD, RD		S	S	SD		
PW-5	S	S, R	R	R		R	R	R	S	S, R	S, R	R	S	S	S		
PW-6				R				R				S, R				S	
W-1S		S, R	R			R	R			S, R	S, R			S	S		42
W-1D		SD	S							SD	S			SD	S		3, 49D, 75
W-2S		S*	S							S	S			S	S		
W-21		S, R	R			R	R			S, R	S, R			S	S		
W-2D																	100, 110, 120, 140, 145
W-2DR			RD	R			RD	R			SD, RD	R			SD		168, 177, 197, 237, 257
W-3S		S*								S				S			45
W-3SR			S								S				S		
W-4S		S	S							S	S			S	S		
W-5D		S*	S	S						S	S	S		S	S	S	4, 5
W-5DD																	
W-6S		S	S							S	S			S	S		
W-6D		S	S							S	S			S	S		
W-7S		S*	S							S	S			S	S		53
W-7D		S*	SD							S	SD			S	SD		
W-8S		S	S							S	S			S	S		32
W-8D		S	S							S	S			S	S		
W-9S		S	S							S	S			S	S		46
W-10S		S, R	S			R				S, R	S			S	S		48D
W-11S		S, R	R	S		R	R			S, R	S, R	S		S	S	S	58

TABLE 3-1  
(Continued)

Sampling Round:	Volatile Organics				Semi-Volatile Organics, Pesticides/PCBs				Metals				Indicator Parameters				SAS Volatile Organics
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	During Drilling
<u>Well I.D.</u>																	
W-110			SD	S							SD	S			SD	S	107
W-12S			S								S				S		
W-13S			S								S				S		
W-14S			S								S				S		
W-15S			S								S				S		
W-16S			S	S							S				S		
W-17S			S	R				R			S	R			S		
W-18I			S								S				S		
W-19S			R	R			R	R			S, R	R			S		49
W-20S			S	S							S	S			S	S	
W-21S			S	S							S	S			S	S	
W-22S			S	S							S	S			S	S	
W-23S			R	R			R	R			S, R	R			S		
W-24S			S	S							S	S			S	S	
W-25S			S	S							S	S			S	S	
W-26S			R	R			R	R			S, R	R			S		66
W-26I			R	R			R	R			S, R	R			S		
W-26D			SD	S							SD	S			SD	S	78, 88, 98, 108
W-27S			S								S				S		
W-27I			S								S				S		
W-27D			SD								SD				SD		155, 167D, 171, 177, 198
W-28S			S								S				S		
W-28D			S								S				S		
W-29S			S								S				S		
W-29D			SD								SD				SD		
W-30S			S								S				S		

TABLE 3-1  
(Continued)

Sampling Round:	Volatile Organics				Semi-Volatile Organics, Pesticides/PCBs				Metals				Indicator Parameters				SAS Volatile <sup>b</sup> Organics
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	During Drilling
<u>Well I.D.</u>																	
W-30D			S								S				S		
W-31S			S								S				S		49
W-32S			S								S				S		
W-32D				RD				RD				SD, RD				SD	
W-33S			S								S				S		
W-34S			R	RD			R	RD			S, R	RD			S		68
W-34I			R	R			R	R			S, R	R			S		80, 90, 100
W-35S			R	R			R	R			S, R	R			S		
W-35I			SD	R				R			SD	R			SD		70, 80, 90, 99
W-36S			S								S				S		
W-36D			S								S				S		158
W-37I			R	R			R	R			S, R	R			S		70, 80, 90, 100
W-39S				S								S				S	
W-39D				SD								SD				SD	
W-40S				S								S				S	
W-40D				S								S				S	150, 177D, 237, 254
W-41S				S								S				S	
W-41D				R				R				S, R				S	117, 137, 157
W-42S				RD				RD				SD, RD				SD	

<sup>a</sup> = Groundwater samples were collected during four sampling rounds occurring in September 1987 (Round 1), November 1987 (Round 2), November 1988 (Round 3), and August 1989 (Round 4). Samples were also collected during well drilling activities. S represents SAS analysis, R represents RAS analysis, and D represents a duplicate sample. The asterisk (\*) indicates a sample was collected but not analyzed because the sample container was broken. Refer to appropriate appendices containing chemical data summaries to determine specific constituents measured in each analysis.

<sup>b</sup> = Values in this column indicate depths (feet below ground surface) at which samples were collected.

**Table 3-2**  
**Summary of Soil Gas Sampling Results**  
**Sturgis Well Field R1/FS**  
**Sturgis, Michigan**

<u>Location</u>	<u>Facility</u>	<u>Date Sampled</u>	<u>ICE</u>	<u>PCE</u>	<u>1,1-DCE</u>	<u>1,2-DCE</u>	<u>1,1,1-TCA</u>	<u>Other-Concentration</u>	<u>Total VOCs</u>
1	WADE	09-Sep-87							N/D
2	WADE	09-Sep-87	BMDL						BMDL
3	WADE	09-Sep-87	2.12						2.12
4	WADE	09-Sep-87	1.57						1.57
5	WADE	09-Sep-87	11.58	BMDL	BMDL			BMDL	24.24
6	WADE	09-Sep-87		12.66					N/D
7	WADE	09-Sep-87							1.63
8	WADE	09-Sep-87	1.63	BMDL					N/D
8 DUP	WADE	09-Sep-87							N/D
9	ACROSS TELEMARK	09-Sep-87		1.44					1.44
10	MCKEE ST.	09-Sep-87							N/D
11	SPENCE WELL	09-Sep-87							BMDL
12	C-H MACHINE	09-Sep-87			BMDL				BMDL
13	C-H MACHINE	09-Sep-87			BMDL				BMDL
14	STUR. ELEC. MOTOR	10-Sep-87							N/D
15	STUR. ELEC. MOTOR	10-Sep-87							N/D
16	STUR. ELEC. MOTOR	10-Sep-87							N/D
17	STUR. ELEC. MOTOR	10-Sep-87							BMDL
18	NW WELDING	10-Sep-87					BMDL		N/D
19	CITY BARN	10-Sep-87							N/D
20	CITY BARN	10-Sep-87							N/D
21	CITY BARN	10-Sep-87							N/D
22	CITY BARN	10-Sep-87							N/D
BLANK									N/D
23	STUR. TOOL & DIE	10-Sep-87							BMDL
24	STUR. TOOL & DIE	10-Sep-87							BMDL
5A	WADE	10-Sep-87	4.28	8.76	BMDL				13.04
25	C-H MACHINE	10-Sep-87			BMDL				BMDL
25 DUP	C-H MACHINE	10-Sep-87			BMDL				BMDL
26	WADE	10-Sep-87							N/D
27	WADE	10-Sep-87							N/D
28	WADE	10-Sep-87							N/D
29	WADE	10-Sep-87							BMDL
30	WADE	10-Sep-87							N/D
31	WADE	10-Sep-87							N/D
31 DUP	WADE	10-Sep-87							N/D
9B	ACROSS TELEMARK	11-Sep-87	BMDL	1.17					1.17
32	ROSS	11-Sep-87							N/D
33	ROSS	11-Sep-87							N/D
34	ROSS	11-Sep-87							N/D
35	ROSS	11-Sep-87							N/D
36	ROSS	11-Sep-87							N/D
36 DUP	ROSS	11-Sep-87							N/D



Table 3-2  
(Continued)

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Location	Facility	Date Sampled	TCE	PCE	1,1-DCE	1,2-DCE	1,1,1-TCA	Other-Concentration	Total VOCs
5B	WADE	11-Sep-87	10.98	16.04					27.02
37	LOSINSKI	11-Sep-87					BMDL		BMDL
38	LOSINSKI	11-Sep-87	37.40				BMDL		37.40
39	TELEMARK	11-Sep-87	BMDL				BMDL		10.72
40	TELEMARK	11-Sep-87		10.72					2.86
41	TELEMARK	11-Sep-87		1.43	1.43		1.47		1.47
42	TELEMARK	12-Sep-87							N/D
43	TELEMARK	12-Sep-87							N/D
43	TELEMARK	12-Sep-87							N/D
43 DUP	TELEMARK	12-Sep-87							N/D
BLANK		12-Sep-87							N/D
44	PARMA	12-Sep-87		2.54					2.54
45	PARMA	12-Sep-87		2.26			3.28		5.54
46	PARMA	12-Sep-87							N/D
47	PARMA	12-Sep-87							N/D
48	PARMA	12-Sep-87							N/D
49	TRI-COUNTY	12-Sep-87					BMDL		BMDL
50	TRI-COUNTY	12-Sep-87							N/D
51	TRI-COUNTY	12-Sep-87							N/D
52	TRI-COUNTY	12-Sep-87							N/D
53 DUP	TRI-COUNTY	12-Sep-87							N/D
5C	WADE	12-Sep-87	8.84	31.80					40.64
BLANK		13-Sep-87							N/D
54	UNITED PAPER	13-Sep-87						TOLUENE	2.16
55	UNITED PAPER	13-Sep-87						TOLUENE	0.22
57	UNITED PAPER	13-Sep-87							N/D
58	UNITED PAPER	13-Sep-87							N/D
59	UNITED PAPER	13-Sep-87							N/D
59 DUP	UNITED PAPER	13-Sep-87							N/D
60	NEWPORT	13-Sep-87	BMDL	103.00			1.10		104.10
61	NEWPORT	13-Sep-87		5.12			3.16		8.28
62	CITY PARK	13-Sep-87							N/D
63	CITY PARK	13-Sep-87							BMDL
64	CITY PARK	13-Sep-87		BMDL					N/D
65	CITY PARK	13-Sep-87							N/D
66	CITY PARK	13-Sep-87							N/D
67	OLD BANDHOLTZ	13-Sep-87						TOLUENE	2.70
68	OLD BANDHOLTZ	13-Sep-87							BMDL
50	WADE	13-Sep-87	20.60	97.80			2.70		118.40
69	AIRPORT	13-Sep-87	BMDL	3.68			BMDL		4.84
70	AIRPORT	13-Sep-87		2.68			1.16		2.68
71	AIRPORT	13-Sep-87					BMDL		N/D
72	AIRPORT	13-Sep-87					1.03	1.530	2.56
73	AIRPORT	13-Sep-87					BMDL		BMDL
74	AIRPORT	13-Sep-87							N/D
75	AIRPORT	13-Sep-87					1.31	2.480	3.79
BLANK		14-Sep-87							N/D

Table 3-2  
(Continued)

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Location	Facility	Date Sampled	TCE	PCE	1,1-DCE	1,2-DCE	1,1,1-TCA	Other-Concentration	Total VOCs
76	AIRPORT	14-Sep-87		1.19					1.19
77	AIRPORT	14-Sep-87							N/D
78	AIRPORT	14-Sep-87							N/D
79	NEWPORT	14-Sep-87	4.94	58.80		1.09	1.14	1.584	67.55
80	NEWPORT	14-Sep-87		1.82			1.54		N/D
81	NEWPORT	14-Sep-87		26.40					35.96
5E	WADE	14-Sep-87	9.56	1.00					1.00
BLANK		14-Sep-87							2.57
82	KIRSCH 2	14-Sep-87					1.52	1.050	3.34
82 DUP	KIRSCH 2	14-Sep-87					BMDL	3.340	1.76
83	KIRSCH 2	14-Sep-87	1.56				0.20		4.24
84	KIRSCH 2	14-Sep-87					4.24		3.62
85	KIRSCH 2	14-Sep-87		4.02			2.42	1.200	8.02
86	KIRSCH 2	14-Sep-87					0.32	3.680	3.36
87	KIRSCH 2	14-Sep-87					1.36	2.000	3.65
88	KIRSCH 2	14-Sep-87					2.04	1.610	3.60
89	KIRSCH 2	14-Sep-87					3.60	BMDL	4.66
90	KIRSCH 2	14-Sep-87					1.66	3.000	2.22
91	KIRSCH 2	14-Sep-87					BMDL	2.220	N/D
BLANK		15-Sep-87							N/D
5F	WADE	15-Sep-87	21.20	44.80					66.00
9A	ACROSS TELEMARK	15-Sep-87		1.81					1.81
92	STYLE LINE	15-Sep-87		1.48					1.48
93	STYLE LINE	15-Sep-87							N/L
94	STYLE LINE	15-Sep-87							BMDL
95	STYLE LINE	15-Sep-87							N/D
96	STYLE LINE	15-Sep-87							N/D
97	KIRSCH 1	15-Sep-87	BMDL	1.65					1.65
98	KIRSCH 1	15-Sep-87					11.74	1.860	13.60
99	KIRSCH 1	15-Sep-87			BMDL		1.66		1.66
100	KIRSCH 1	15-Sep-87					2.02		2.02
101	KIRSCH 1	15-Sep-87					1.52		338.72
102	KIRSCH 1	15-Sep-87	47.20	290.00			BMDL		7.16
102 DUP	KIRSCH 1	15-Sep-87	BMDL	7.16					4.74
103	KIRSCH 1	15-Sep-87		4.74					2.50
104	KIRSCH 1	15-Sep-87		2.50					
105	AIRPORT	16-Sep-87			1.42		12.76	2.780	16.96
106	AIRPORT	16-Sep-87			1.25		6.94	N/D	9.38
107	AIRPORT	16-Sep-87			1.24		5.08	1.190	7.66
108	AIRPORT	16-Sep-87			1.32		9.54	2.080	12.94
109	AIRPORT	16-Sep-87					BMDL	1.910	1.91
110	TELEMARK	16-Sep-87					BMDL		BMDL
110 DUP	TELEMARK	16-Sep-87					BMDL		BMDL
111	TELEMARK	16-Sep-87					4.84	1.270	6.11
BLANK		16-Sep-87							N/D
112	TELEMARK	16-Sep-87					4.76	2.220	6.88
113	TELEMARK	16-Sep-87					10.08	1.770	14.51
114	TELEMARK	16-Sep-87		1.36	1.30		23.40	1.690	26.84

Location	Facility	Date Sampled	ICE	PCE	1,1-DCE	1,2-DCE	1,1,1-ICA	Other-Concentration	Total VOCs
115	TELEMARK	16-Sep-87			2.04		23.60	TOLUENE BENZENE	27.09 24.84
116	TELEMARK	16-Sep-87			1.92		20.60	TOLUENE	28.57
117	TELEMARK	16-Sep-87			1.95		21.60	TOLUENE	3.30
118	UNITED DRIVE	16-Sep-87					1.74	TOLUENE	12.99
119	UNITED DRIVE	16-Sep-87			1.43		9.18	TOLUENE	
120	UNITED DRIVE	16-Sep-87			1.77		22.60	TOLUENE BENZENE	26.20 14.97
121	UNITED DRIVE	16-Sep-87			1.55		12.08	TOLUENE	74.80
56	WADE	16-Sep-87	35.00	39.80					
Round Two									
1	FOUNDRY	26-Oct-87							N/D
1 DUP	FOUNDRY	26-Oct-87							N/D
2	FOUNDRY	26-Oct-87					BMDL		BMDL
3	FOUNDRY	26-Oct-87							N/D
4	FOUNDRY	26-Oct-87							N/D
5	FOUNDRY	26-Oct-87							N/D
6	FOUNDRY	26-Oct-87							N/D
7	FOUNDRY	26-Oct-87							N/D
8	FOUNDRY	26-Oct-87							N/D
9	FOUNDRY	26-Oct-87							N/D
10	FOUNDRY	26-Oct-87							N/D
11	FOUNDRY	26-Oct-87							N/D
12	FOUNDRY	26-Oct-87							N/D
13	FOUNDRY	26-Oct-87							N/D
14	FOUNDRY	26-Oct-87							N/D
BLANK	FOUNDRY	26-Oct-87							N/D
15	N. CLAY ST.	27-Oct-87							N/D
15 DUP	N. CLAY ST.	27-Oct-87							N/D
16	N. CLAY ST.	27-Oct-87							N/D
17	N. CLAY ST.	27-Oct-87							N/D
18	N. CLAY ST.	27-Oct-87							N/D
BLANK	N. CLAY ST.	27-Oct-87							N/D
19	N. CLAY ST.	27-Oct-87							N/D
20	N. CLAY ST.	27-Oct-87							N/D
21	N. CLAY ST.	27-Oct-87							N/D
22	N. CLAY ST.	27-Oct-87							N/D
23	N. CLAY ST.	27-Oct-87							N/D
24	N. CLAY ST.	27-Oct-87							N/D
25	N. CLAY ST.	27-Oct-87							N/D
26	N. CLAY ST.	27-Oct-87							N/D
27	N. CLAY ST.	27-Oct-87							N/D
28	N. CLAY ST.	27-Oct-87							N/D
29	N. CLAY ST.	27-Oct-87							N/D
30	PRAIRIE ST.	28-Oct-87							N/D
							3.58	BMDL	3.58

Table 3-2  
(Continued)

Page 5 of 9

<u>Location</u>	<u>Facility</u>	<u>Date Sampled</u>	<u>ICE</u>	<u>PCE</u>	<u>1,1-DCE</u>	<u>1,2-DCE</u>	<u>1,1,1-TCA</u>	<u>Other-Concentration</u>	<u>Total VOCs</u>
30 DUP	PRAIRIE ST.	28-Oct-87					4.04	BMDL	4.04
31	PRAIRIE ST.	28-Oct-87							N/D
BLANK	PRAIRIE ST.	28-Oct-87							N/D
32	PRAIRIE ST.	28-Oct-87							N/D
33	PRAIRIE ST.	28-Oct-87							N/D
34	PRAIRIE ST.	28-Oct-87							N/D
35	PRAIRIE ST.	28-Oct-87							N/D
36	PRAIRIE ST.	28-Oct-87							N/D
37	PRAIRIE ST.	28-Oct-87							N/D
38	PRAIRIE ST.	28-Oct-87							N/D
39	PRAIRIE ST.	28-Oct-87							N/D
40	PRAIRIE ST.	28-Oct-87							N/D
41	PRAIRIE ST.	28-Oct-87							N/D
42	PRAIRIE ST.	28-Oct-87							N/D
43	PRAIRIE ST.	28-Oct-87							N/D
44	PRAIRIE ST.	28-Oct-87							N/D
5H	WADE	28-Oct-87	2.56	4.58			4.04		7.14

Table 3-2  
(Continued)

Concentrations are in ug/l Air

Location	Facility	Date Sampled	ICE	PCE	Other-Concentration	Total VOCs
5L	WADE	21-Jun-88	19.9	74.4		94.3
5L	WADE	21-Jun-88	19.6	78.8		98.4
201 DUP	WADE	21-Jun-88	1.24	BMDL		1.24
202	WADE	21-Jun-88	1.25	BMDL		1.25
203	WADE	21-Jun-88	5.88	BMDL		5.88
204	WADE	21-Jun-88	BMDL	1.04		1.04
205	WADE	21-Jun-88	BMDL			BMDL
206	WADE	21-Jun-88	BMDL			BMDL
207	WADE	21-Jun-88	BMDL			BMDL
208	WADE	21-Jun-88				N/D
209 DUP	WADE	21-Jun-88				N/D
210	WADE	21-Jun-88				N/D
1 FB	BLANK	21-Jun-88				N/D
211	WADE	21-Jun-88				N/D
212 DUP	WADE	21-Jun-88				N/D
213	KIRSCH #1	22-Jun-88				N/D
214	KIRSCH #1	22-Jun-88				N/D
215 DUP	KIRSCH #1	22-Jun-88				N/D
216	KIRSCH #1	22-Jun-88	BMDL			BMDL
217 DUP	KIRSCH #1	22-Jun-88	BMDL			BMDL
218	KIRSCH #1	22-Jun-88				N/D
219	KIRSCH #1	22-Jun-88				N/D
220	KIRSCH #1	22-Jun-88				N/D
221	KIRSCH #1	22-Jun-88				N/D
222	KIRSCH #1	22-Jun-88				N/D
223 DUP	KIRSCH #1	22-Jun-88	4.94	BMDL		4.94
224	KIRSCH #1	22-Jun-88	4.38	BMDL		4.38
225	KIRSCH #1	22-Jun-88	BMDL			BMDL
226	KIRSCH #1	22-Jun-88				N/D
227	KIRSCH #1	22-Jun-88				N/D
228 DUP	KIRSCH #1	22-Jun-88	8.36			8.36
229	KIRSCH #1	22-Jun-88	8.10			8.10
5M	WADE	22-Jun-88	14.5	50.4		64.9
5M DUP	WADE	22-Jun-88	15.6	52.0		67.6
5M DUP	WADE	22-Jun-88	13.5	48.6		62.1
2 FB	BLANK	22-Jun-88	15.2	51.0		66.2
230	TELEMARK	23-Jun-88				N/D

Table 3-2  
(Continued)

Location	Facility	Date Sampled	TCE	PCE	Other-Concentration	Total VOCs
231	TELEMARK	23-Jun-88				N/D
232	TELEMARK	23-Jun-88				N/D
233	TELEMARK	23-Jun-88				N/D
234	TELEMARK	23-Jun-88				N/D
235	TELEMARK	23-Jun-88				N/D
236	TELEMARK	23-Jun-88				N/D
237	TELEMARK	23-Jun-88				N/D
237 DUP	TELEMARK	23-Jun-88				N/D
5N	WADE	23-Jun-88	15.9	73.6		89.5
5N	WADE	23-Jun-88	15.0	69.0		84.0
238	TELEMARK	23-Jun-88	BMDL	BMDL		BMDL
238 DUP	TELEMARK	23-Jun-88	BMDL	BMDL		BMDL
239	TELEMARK	23-Jun-88				BMDL
240	TELEMARK	23-Jun-88	15.7	BMDL		15.7
240 DUP	TELEMARK	23-Jun-88	15.2	BMDL		5.2
241	TELEMARK	23-Jun-88	BMDL	BMDL		BMDL
242	TELEMARK	23-Jun-88				N/D
243	TELEMARK	23-Jun-88				N/D
244	TELEMARK	23-Jun-88				N/D
245	TELEMARK	23-Jun-88				BMDL
246	TELEMARK	23-Jun-88				N/D
247	TELEMARK	23-Jun-88				N/D
248	TELEMARK	24-Jun-88				N/D
248 DUP	TELEMARK	24-Jun-88				N/D
249	TELEMARK	24-Jun-88				N/D
249 DUP	TELEMARK	24-Jun-88				N/D
250	E. MAIN E of N. PROSPECT	24-Jun-88			TOLUENE BMDL	N/D
251	E. MAIN E of N. PROSPECT	24-Jun-88			1,1,1-TCA 1.18	1.18
252	E. MAIN E of N. PROSPECT	24-Jun-88			TOLUENE BMDL	N/D
					1,1-DCE BMDL	
					1,1,1-TCA 3.24	3.24
3	BLANK FB	24-Jun-88				N/D
4	BLANK FB	24-Jun-88				N/D
253	E. MAIN E of N. PROSPECT	24-Jun-88				N/D
253 DUP	E. MAIN E of N. PROSPECT	24-Jun-88				N/D
254	E. MAIN E of N. PROSPECT	24-Jun-88				N/D
255	E. MAIN E of N. PROSPECT	24-Jun-88				N/D
256	E. MAIN E of N. PROSPECT	24-Jun-88				N/D
257	E. MAIN E of N. PROSPECT	24-Jun-88				N/D
258	E. MAIN E of N. PROSPECT	24-Jun-88				N/D
258 DUP	E. MAIN E of N. PROSPECT	24-Jun-88				BMDL
50	WADE	24-Jun-88	19.1	64.0	1,1,1-TCA BMDL	BMDL
259	N. PROSPECT N of E. MAIN	24-Jun-88				83.1
260	N. PROSPECT N of E. MAIN	24-Jun-88				N/D
251	N. PROSPECT N of E. MAIN	24-Jun-88				N/D

Table 3-2  
(Continued)

Location	Facility	Date Sampled	ICE	PCE	Other-Concentration	Total VOCs
262	E. MAIN W of N. PROSPECT	24-Jun-88				N/D
262 DUP	E. MAIN W of N. PROSPECT	24-Jun-88				N/D
263	E. MAIN W of N. PROSPECT	24-Jun-88				N/D
264	E. MAIN W of N. PROSPECT	24-Jun-88				N/D
264 DUP	E. MAIN W of N. PROSPECT	24-Jun-88				N/D
265	SUSAN CT. N of E. HATCH	25-Jun-88				N/D
266	SUSAN CT. N of E. HATCH	25-Jun-88				N/D
267	SUSAN CT. N of E. HATCH	25-Jun-88				N/D
268	SUSAN CT. N of E. HATCH	25-Jun-88				N/D
269	SUSAN CT. N of E. HATCH	25-Jun-88				N/D
5	BLANK FB	25-Jun-88				N/D
270	KIRSCH #1	25-Jun-88				N/D
271	KIRSCH #1	25-Jun-88				N/D
271 DUP	KIRSCH #1	25-Jun-88				N/D
5p	WADE	25-Jun-88	12.4	60.4		72.8
272	KIRSCH #1	25-Jun-88				N/D
272 DUP	KIRSCH #1	25-Jun-88				N/D
273	E. MAIN E of N. PROSPECT	25-Jun-88				BMDL
274	E. MAIN E of N. PROSPECT	25-Jun-88				N/D
274 DUP	E. MAIN E of N. PROSPECT	25-Jun-88				N/D
275	E. MAIN & LAKEVIEW	25-Jun-88				N/D
276	E. MAIN & LAKEVIEW	25-Jun-88				N/D
276 DUP	E. MAIN & LAKEVIEW	25-Jun-88				N/D
277	AIRPORT	26-Jun-88				N/D
278	AIRPORT	26-Jun-88				N/D
278 DUP	AIRPORT	26-Jun-88				N/D
279	AIRPORT	26-Jun-88				N/D
6	BLANK FB	26-Jun-88				N/D
280	AIRPORT	26-Jun-88				N/D
281	AIRPORT	26-Jun-88				N/D
282	AIRPORT	26-Jun-88				N/D
282 DUP	AIRPORT	26-Jun-88				N/D
5q	WADE	26-Jun-88	18.1	84.6		103
283	AIRPORT	26-Jun-88				N/D
284	AIRPORT	26-Jun-88				N/D
285	AIRPORT	26-Jun-88				N/D
285 DUP	AIRPORT	26-Jun-88				N/D
286	AIRPORT	26-Jun-88				N/D
286 DUP	AIRPORT	26-Jun-88				N/D
287	STURGIS IRON & METAL	27-Jun-88			TOLUENE	N/D
288	STURGIS IRON & METAL	27-Jun-88			BMDL	BMDL
287	STURGIS IRON & METAL	27-Jun-88				N/D
289	STURGIS IRON & METAL	27-Jun-88				N/D
290	STURGIS IRON & METAL	27-Jun-88				N/D
291	STURGIS IRON & METAL	27-Jun-88				N/D
291 DUP	STURGIS IRON & METAL	27-Jun-88				N/D
7	BLANK FB	27-Jun-88				N/D

Table 3-2  
(Continued)

Location	Facility	Date Sampled	ICE	PCE	Other-Concentration	Total VOCs
292	STURGIS IRON & METAL	27-Jun-88				N/D
292 DUP	STURGIS IRON & METAL	27-Jun-88				N/D
5R	WADE	27-Jun-88	7.72	60.0		67.7
293	STURGIS IRON & METAL	27-Jun-88				N/D
293 DUP	STURGIS IRON & METAL	27-Jun-88				N/D
294	STURGIS IRON & METAL	27-Jun-88				N/D
295	STURGIS IRON & METAL	27-Jun-88				N/D
296	STURGIS IRON & METAL	27-Jun-88				N/D
2-100	CLASSIC WOOD RESTORATION	23-Jul-88				N/D
2-101	CLASSIC WOOD RESTORATION	23-Jul-88				N/D
2-101 DUP	CLASSIC WOOD RESTORATION	23-Jul-88				N/D
2-102	CLASSIC WOOD RESTORATION	23-Jul-88				N/D
2-103	CLASSIC WOOD RESTORATION	23-Jul-88				N/D
2-104	CLASSIC WOOD RESTORATION	23-Jul-88				N/D
2-105	E. HATCH W of N. PROSPECT	25-Jul-88	8.20			8.20
2-106	E. HATCH W of N. PROSPECT	25-Jul-88	4.00			4.00
2-107	E. HATCH W of N. PROSPECT	25-Jul-88	27.8			27.8
2-108	E. HATCH W of N. PROSPECT	25-Jul-88	BMDL			BMDL
2-109	E. HATCH W of N. PROSPECT	25-Jul-88	BMDL			BMDL
2-110	E. HATCH W of N. PROSPECT	25-Jul-88	BMDL			BMDL
2-110 DUP	E. HATCH W of N. PROSPECT	25-Jul-88	BMDL			BMDL
2-111	E. HATCH W of N. PROSPECT	25-Jul-88	BMDL			BMDL
2-112	E. HATCH W of N. PROSPECT	26-Jul-88	8.80			8.80
2-113	E. HATCH W of N. PROSPECT	26-Jul-88	1.20			1.20
2-114	E. HATCH W of N. PROSPECT	26-Jul-88	BMDL			BMDL
2-114 DUP	KIRSCH #1	26-Jul-88	15.8	4.30		20.1
2-115	KIRSCH #1	26-Jul-88	5.30	5.30		24.8
2-116	KIRSCH #1	27-Jul-88	1195.	BMDL		1195
8	BLANK FB	27-Jul-88	341	BMDL	1,2-DCE BMDL	341
2-117	KIRSCH #1	27-Jul-88	1.00	BMDL		1.00
2-118	KIRSCH #1	27-Jul-88	22.0	BMDL		22.0
2-119	KIRSCH #1	27-Jul-88	13.2	BMDL		13.2
2-120	KIRSCH #1	27-Jul-88	1.40			1.40
2-121	KIRSCH #1	27-Jul-88	7.30	BMDL	1,2-DCE 1.00	8.30
2-121	KIRSCH #1	27-Jul-88	1.00	BMDL		1.00

NOTE: N/D = VOCs were not detected in the sample

BMDL = VOCs were detected in sample below the method detection limit of 1 ug/l. Total 7

Concentrations are in ug/L



TABLE 3-3

Summary of Contract Laboratory Program Analysis  
of Subsurface Soil Samples  
Sturgis Well Field RI/FS  
Sturgis, Michigan

<u>Sample</u>		<u>Volatile Organics</u>	<u>Semivolatile Organics, Pesticide/PBCs, Metals</u>
<u>Location</u>	<u>Depth</u>		
SB01	06	R	R
SB01R	02.5	S	
	10	S	
SB02	02.5	R	R
	05	R	R
	07.5	R	R
	10	R	R
	15	R	R
SB06	02.5	R	R
	05	R	R
	20	S	
	25	S	
	30	S	
	40	S	
	50	S	
SB07	02.5	S	
	05	S	
	07.5	S	
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	
SB09	02.5	S, R	R
	05	S, R	R
	10	S	
	15	S	
	20	S	
	25	S	
SB10	01.5	S, R	R
	04.5	S, R	R
	10	S	
	15	S	
	20	S	
	25	S	
SB11	01.5	S, R	R
	04.5	S, R	R
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	

TABLE 3-3  
(Continued)

<u>Sample</u>		<u>Volatile Organics</u>	<u>Semivolatile Organics, Pesticide/PBCs, Metals</u>
<u>Location</u>	<u>Depth</u>		
SB12	02	R	R
	05	R	R
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	
SB13	01.5	R	R
	05	R	R
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	
SB14	03.5	R	R
	06	R	R
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	
SB15	01.5	R	R
	05	R	R
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	
SB16	01.5	S	R
	05	S	R
	10	S	
	15	S	
	20	S	
	30	S	
	01.5	S	R
SB17	05	S	R
	10	S	
	15	S	
	20	S	
	30	S	
	02	R	R
	06	RD	RD
SB18	10	S	
	30	S	
	02	RD	RD
	04	R	R
	06	R	R
	15	S	
	30	S	

TABLE 3-3  
(Continued)

Sample		Volatile Organics	Semivolatile Organics, Pesticide/PBCs, Metals
Location	Depth		
SB20	02	R	R
	04	R	R
	06	R	R
SB20	15	S	
	30	S	
SB21	02	R	R
	04	R	R
	06	R	R
	20	SD	
W4S	05	S	
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	
W6D	22	S	
	27	S	
W9S	01	S, RD	
	05	S	
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	
	40	S	
W10S	01	S	
	05	S	
	10	S	
	20	S	
	25	S	
W11S	30	S	
	01	S	
	05	S	
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	
	35	S	
	41	S	
	50	S	
W26S	60	S	
	21	S	
	26	S	
	41	S	

TABLE 3-3  
(Continued)

Sample		Volatile Organics	Semivolatile Organics, Pesticide/PBCs, Metals
Location	Depth		
W33S	01.5	R	R
	05	R	R
	10	S	
	15	S	
	20	S	
	25	S	
	30	S	
W40S	15	SD	
	25	S	
	35	S	
	50	S	
W41S	05	S	
	25	S	
	30	S	
	50	S	
W42S	02.5	R	R
	15	S	
	20	S	
	35	S	
	45	S	

Notes: Subsurface soil samples were collected during three phases occurring in October 1987 (Phase 1), July through September 1988 (Phase 2), and May and August 1989 (Phase 2B). S represents SAS analysis, R represents RAS analysis and D represents a duplicate sample.

Table 5-1  
Grain Size Analyses  
Sturgis Well Field RI/FS  
Sturgis, Michigan

<u>Sample Location</u>	<u>Depth (ft)</u>	<u>%P200</u>	<u>LL</u>	<u>PI</u>	<u>Classification</u>	<u>Hydrostratigraphic Unit Code*</u>
W05D	70-72	61.8	18	7	CL-ML	2
W06D	119-119.5	42.1	14	6	SC-SM	2
W07D	118-120	50.2	16	6	CL-ML	4
W07D	128-130	44.0	17	8	SC	4
W08D	67-68	40.7	16	6	SC-SM	2
W08D	138-139	91.4	20	6	CL-ML	4
W10S	38.5-40	9.5	-	-	SP-SM	1
W11D	127-129	41.8	14	5	SC-SM	4
W12S	24-26	5.4	-	-	SP-SM	1
W28D	127-137	50.7	21	12	CL	4
W29S	54-56	48.9	17	5	SC-SM	2
W30D	117-118	42.4	13	5	SC-SM	4
W30D	137-138	54.3	17	9	CL	4
W35S	48.5-50	34.2	-	-	SM	1
W35S	60	4.8	-	-	SP	1
W35I	70	9.3	-	-	SP-SM	1
W36D	107-117	29.2	13	3	SM	3

\* Hydrostratigraphic Unit Codes

- 1 - Upper outwash unit
- 2 - Upper till unit
- 3 - Middle outwash unit
- 4 - Intermediate-depth till unit

**GROUNDWATER ELEVATIONS  
STURGIS WELL FIELD RI/FS  
STURGIS, MICHIGAN**

WELL NUMBER	19-Nov-87 GROUNDWATER ELEVATION	09-Dec-87 GROUNDWATER ELEVATION	28-Dec-87 GROUNDWATER ELEVATION	11-Jan-88 GROUNDWATER ELEVATION	25-Jan-88 GROUNDWATER ELEVATION	20-Oct-88 GROUNDWATER ELEVATION	8-Nov thru 14-Nov-88 GROUNDWATER ELEVATION	10-Jan-89 GROUNDWATER ELEVATION
W-1S	867.33	867.28	867.38	867.38	867.34	866.03	866.03	866.43
W-1D	864.45	865.14	865.74	865.55	865.38	863.84	864.00	864.65
W-2S	866.20	865.98	866.51	866.42	866.32	864.78	864.83	865.45
W-2I	866.09	866.06	866.44	866.35	866.21	864.65	864.73	865.39
W-2D	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
W-2DR	(2)	(2)	(2)	(2)	(2)	864.57	864.67	865.32
W-3S	866.48	866.33	866.81	866.51	866.41	(1)	(1)	(1)
W-3SR	(2)	(2)	(2)	(2)	(2)	864.85	865.00	865.59
TW-83A	864.64	864.37	864.90	864.48	864.42	NA	863.13	863.90
W-4S	872.88	873.09	872.89	872.56	872.47	872.36	871.30	872.09
GW-2	864.42	864.18	865.20	864.37	864.48	NA	863.08	864.14
GW-1	870.00	870.02	869.98	869.73	869.58	869.13	869.03	868.89
W-5D	864.33	864.11	865.16	864.29	864.39	863.01	863.33	863.84
W-5DD	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-6S	879.09	878.35	877.83	877.08	877.20	NA	878.54	877.21
W-6D	864.21	863.94	865.04	864.09	864.24	NA	862.90	863.77
W-7S	866.72	866.47	866.93	866.68	866.56	864.95	865.10	865.63
W-7D	863.88	863.71	864.49	863.67	864.04	862.29	862.64	863.51
W-8S	874.19	874.09	874.16	874.21	874.30	874.22	874.22	874.18
W-8D	865.05	863.66	864.16	864.74	863.98	862.34	862.56	863.03
W-9S	868.01	867.94	868.02	867.99	867.94	867.11	867.09	867.33
W-10S	866.76	866.55	867.10	866.80	866.68	865.13	865.33	865.83
W-11S	870.76	869.69	869.61	869.59	869.54	868.36	868.36	868.44
W-11D	(2)	(2)	(2)	(2)	(2)	866.05	866.13	866.66
W-12S	(2)	(2)	(2)	(2)	(2)	864.75	864.75	865.25
W-13S	(2)	(2)	(2)	(2)	(2)	864.86	864.88	865.40
W-14S	(2)	(2)	(2)	(2)	(2)	865.16	865.21	865.74
W-15S	(2)	(2)	(2)	(2)	(2)	865.13	865.42	865.90
W-16S	(2)	(2)	(2)	(2)	(2)	865.21	865.45	865.89
W-17S	(2)	(2)	(2)	(2)	(2)	865.90	865.95	866.35
GW-7	867.49	867.41	867.53	867.54	867.48	866.23	866.23	866.58
W-18I	(2)	(2)	(2)	(2)	(2)	863.66	863.81	864.53
W-19S	(2)	(2)	(2)	(2)	(2)	864.22	864.20	864.62
W-20S	(2)	(2)	(2)	(2)	(2)	869.34	869.29	869.19
W-21S	(2)	(2)	(2)	(2)	(2)	869.22	869.19	869.12
W-22S	(2)	(2)	(2)	(2)	(2)	868.39	868.39	868.44
W-23S	(2)	(2)	(2)	(2)	(2)	867.97	867.97	868.09
W-24S	(2)	(2)	(2)	(2)	(2)	868.07	868.06	868.19
W-25S	(2)	(2)	(2)	(2)	(2)	867.29	867.32	867.55
W-26S	(2)	(2)	(2)	(2)	(2)	866.33	866.38	NA
W-26I	(2)	(2)	(2)	(2)	(2)	866.53	866.63	NA
W-26D	(2)	(2)	(2)	(2)	(2)	865.52	865.65	NA
W-27S	(2)	(2)	(2)	(2)	(2)	865.64	865.69	866.13
W-27I	(2)	(2)	(2)	(2)	(2)	864.09	864.29	864.82
W-27D	(2)	(2)	(2)	(2)	(2)	863.08	864.33	864.83
W-28S	(2)	(2)	(2)	(2)	(2)	865.79	865.93	866.43
W-28D	(2)	(2)	(2)	(2)	(2)	865.42	865.56	866.12
W-29S	(2)	(2)	(2)	(2)	(2)	872.84	872.76	872.58
W-29D	(2)	(2)	(2)	(2)	(2)	863.43	863.69	864.15
W-30S	(2)	(2)	(2)	(2)	(2)	865.93	866.03	866.46
W-30D	(2)	(2)	(2)	(2)	(2)	864.36	864.47	865.13
W-31S	(2)	(2)	(2)	(2)	(2)	869.43	869.38	869.68
W-32S	(2)	(2)	(2)	(2)	(2)	865.44	865.59	865.98
W-32D	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-33S	(2)	(2)	(2)	(2)	(2)	866.01	866.06	866.43
W-34S	(2)	(2)	(2)	(2)	(2)	868.64	867.67	867.85
W-34I	(2)	(2)	(2)	(2)	(2)	867.46	867.49	867.70
W-35S	(2)	(2)	(2)	(2)	(2)	865.59	865.68	866.14
W-34SR	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-35I	(2)	(2)	(2)	(2)	(2)	865.52	865.61	866.09
W-36S	(2)	(2)	(2)	(2)	(2)	866.19	866.28	866.74
W-36D	(2)	(2)	(2)	(2)	(2)	864.81	865.06	NA
W-37I	(2)	(2)	(2)	(2)	(2)	865.14	865.20	865.76
W-39S	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)

**TABLE 5-2**  
**(Continued)**

(Continued)

WELL NUMBER	19-Nov-87 GROUNDWATER ELEVATION	09-Dec-87 GROUNDWATER ELEVATION	28-Dec-87 GROUNDWATER ELEVATION	11-Jan-88 GROUNDWATER ELEVATION	25-Jan-88 GROUNDWATER ELEVATION	20-Oct-88 GROUNDWATER ELEVATION	8-Nov thru 14-Nov-88 GROUNDWATER ELEVATION	10-Jan-89 GROUNDWATER ELEVATION
W-39D	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-40S	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-40D	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-41S	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-41D	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-42S	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-1A	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-1B	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-1C	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-2B	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-2C	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-3A	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-3C	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-4	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-6	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-3	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-8	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-84A	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
W-1S	866.51	866.94	866.89	867.00	866.97	866.94	866.90	866.90
W-1D	865.07	864.88	864.65	865.18	865.32	865.36	865.43	865.43
W-2S	865.66	865.56	865.51	865.81	865.93	865.96	866.04	866.04
W-21	865.65	865.53	865.42	865.73	865.95	865.96	866.04	866.04
W-2D	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
W-2DR	865.57	865.47	865.31	865.70	865.91	865.90	865.97	865.97
W-3S	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
W-3SR	865.84	865.74	865.80	866.01	866.15	866.18	866.19	866.19
W-83A	864.11	863.94	863.62	864.26	864.55	864.35	864.33	864.33
W-4S	872.09	872.53	872.81	872.84	872.72	872.64	872.64	872.64
W-4	864.42	863.87	863.71	864.47	864.74	864.74	864.84	864.84
W-2	868.88	869.10	869.63	869.71	869.64	869.54	869.45	869.45
W-1	864.11	863.55	863.86	864.76	864.47	864.50	864.52	864.52
W-5D	(3)	(3)	878.83	864.02	864.28	864.20	864.23	864.23
W-50D	878.15	863.23	863.72	866.11	864.11	864.32	871.56	871.56
W-6S	864.01	865.86	865.96	863.78	878.15	878.32	864.35	864.35
W-6D	865.82	863.27	863.14	874.68	874.59	874.45	869.43	869.43
W-7S	863.79	874.12	862.98	864.79	863.84	864.88	867.97	867.97
W-7D	874.27	864.39	869.26	868.12	868.09	868.05	866.43	866.43
W-8S	864.68	873.11	866.05	866.19	866.33	866.38	869.07	869.07
W-8D	867.45	866.02	866.00	866.33	865.78	865.78	865.01	865.01
W-9S	866.08	868.53	866.77	866.77	865.87	866.13	866.09	866.09
W-10S	868.50	866.50	866.71	865.80	866.02	866.42	866.39	866.39
W-11S	866.81	865.40	865.51	865.93	866.31	866.44	866.47	866.47
W-12S	865.54	865.66	865.74	866.22	866.41	866.41	866.83	866.83
W-13S	866.13	865.95	866.13	866.22	866.34	866.34	866.88	866.88
W-14S	866.10	866.05	866.05	866.93	867.13	867.13	867.26	867.26
W-15S	866.11	866.08	867.09	867.17	865.27	865.27	867.51	867.51
W-16S	866.44	866.88	867.81	865.10	865.17	865.17	869.80	869.80
W-17S	866.66	864.77	865.09	865.18	869.91	869.91	869.10	869.10
W-17S	864.95	864.89	869.78	869.88	869.86	869.86	869.77	869.77
W-181	864.69	869.21	869.70	869.81	869.14	869.14	869.14	869.14
W-19S	869.26	869.03	869.00	869.11	868.76	868.76	868.87	868.87
W-20S	869.53	868.41	868.62	868.71	868.84	868.84	868.28	868.28
W-21S	868.53	868.05	868.05	868.81	868.12	868.12	867.52	867.52
W-23S	868.17	868.30	868.05	868.12	867.26	867.26	866.11	866.11
W-24S	868.27	867.59	867.12	867.44	867.52	867.52	866.52	866.52
W-25S	867.63	866.71	867.33	867.44	866.38	866.38	866.52	866.52
W-26S	866.76	866.98	867.02	867.02	866.38	866.38	866.52	866.52
W-261	866.46	866.46	866.46	866.46	866.46	866.46	866.46	866.46
W-26D	874.32	874.32	874.32	874.32	874.32	874.32	874.32	874.32

TABLE 5-2  
(Continued)

WELL NUMBER	31-Jan-89 GROUNDWATER ELEVATION	26-Apr-89 GROUNDWATER ELEVATION	14-Aug-89 GROUNDWATER ELEVATION	13-Sep-89 GROUNDWATER ELEVATION	03-Oct-89 GROUNDWATER ELEVATION	25-Oct-89 GROUNDWATER ELEVATION	15-Nov-89 GROUNDWATER ELEVATION
W-27S	866.19	866.44	NA	NA	866.62	866.64	NA
W-27I	865.29	865.23	864.89	NA	NA	865.52	865.59
W-27D	865.33	865.28	865.02	865.21	865.64	865.57	865.66
W-28S	866.53	866.29	866.61	866.73	866.82	866.78	866.86
W-28D	866.21	866.01	866.27	866.36	866.31	866.30	866.37
W-29S	872.67	872.48	873.41	873.35	873.17	873.06	872.94
W-29D	865.63	865.50	864.21	865.45	865.91	865.93	865.98
W-30S	866.55	866.59	866.81	866.93	866.99	867.04	867.03
W-30D	865.36	865.24	865.06	865.52	865.62	865.58	865.63
W-31S	869.62	869.85	870.30	870.38	870.24	870.14	870.03
W-32S	866.07	867.16	866.38	866.49	866.53	866.54	866.49
W-32D	(3)	(3)	864.65	865.02	865.33	865.41	865.49
W-33S	866.50	866.78	866.88	866.98	866.98	866.95	866.91
W-34S	867.96	868.11	(4)	(4)	(4)	(4)	(4)
W-34SR	(3)	(3)	868.42	868.49	868.54	868.55	868.52
W-34I	867.78	867.52	868.18	868.25	868.31	868.32	868.29
W-35S	866.24	866.22	866.34	866.59	866.65	866.68	866.69
W-35I	866.21	866.18	866.46	866.51	866.61	866.54	866.64
W-36S	866.90	866.84	866.98	867.05	867.15	867.18	867.26
W-36D	865.90	865.63	865.57	865.91	865.90	862.71	865.90
W-37I	865.96	865.82	865.93	866.13	866.26	866.28	866.33
W-39S	(3)	(3)	867.20	867.24	867.18	867.07	866.97
W-39D	(3)	(3)	862.96	864.24	863.93	864.01	863.97
W-40S	(3)	(3)	866.09	NA	NA	866.45	866.46
W-40D	(3)	(3)	864.54	865.19	865.33	865.22	865.25
W-41S	(3)	(3)	869.21	868.36	869.45	869.38	869.26
W-41D	(3)	(3)	863.60	864.24	864.49	864.34	864.25
W-42S	(3)	(3)	868.15	868.24	868.25	868.28	NA
MW-1A	869.19	869.43	870.89	871.29	871.17	870.88	870.41
MW-1B	862.61	862.46	842.57	862.87	862.95	863.04	862.87
MW-1C	862.15	861.98	NA	861.65	862.80	862.90	862.49
MW-2B	865.57	865.46	865.60	866.37	865.87	865.94	865.91
MW-2C	864.65	864.39	864.37	864.82	864.83	864.96	864.76
MW-3A	866.52	866.46	866.75	866.84	866.91	867.06	867.02
MW-3C	863.83	863.41	862.95	863.65	864.00	863.73	863.35
MW-4	878.20	880.60	880.36	878.20	877.73	880.57	877.54
MW-6	864.11	863.54	863.83	864.21	864.47	864.32	864.25
GW-3	866.95	867.07	867.42	867.52	867.45	867.38	868.33
GW-8	865.20	864.95	865.99	862.27	865.41	865.42	865.51
TW-84A	865.27	865.13	860.11	863.78	864.96	865.48	865.49

NOTES:

- (1) = WELL DAMAGED AND REPLACED IN PHASE II
- (2) = WELL INSTALLED IN PHASE II
- (3) = WELL INSTALLED IN PHASE IIB
- (4) = WELL DAMAGED AND REPLACED IN PHASE IIB



**TABLE 5-3**  
**VERTICAL GROUNDWATER GRADIENTS**  
**STURGIS WELL FIELD RI/FS**  
**STURGIS, MICHIGAN**

<u>WELL NEST IDENTIFIERS</u>	<u>19-Nov-87</u>	<u>09-Dec-87</u>	<u>28-Dec-87</u>	<u>11-Jan-88</u>	<u>25-Jan-88</u>	<u>20-Oct-88</u>	<u>8-Nov thru 14-Nov-88</u>	<u>10-Jan-89</u>	<u>31-Jan-89</u>
W-1S/S-1D	-0.0275	-0.0205	-0.0157	-0.0175	-0.0187	-0.0212	-0.0197	-0.0172	-0.0138
W-2S/W-2I	-0.0024	0.0017	-0.0015	-0.0015	-0.0024	-0.0029	-0.0022	-0.0013	-0.0002
W-2I/W-2DR	INSTALLED W-2DR IN PHASE 2 TO REPLACE W-2D					-0.0007	-0.0005	-0.0006	-0.0007
W-2S/W-2DR	INSTALLED W-2DR IN PHASE 2 TO REPLACE W-2D					-0.0013	-0.0010	-0.0008	-0.0006
W-3S/TW-83A	-0.0146	-0.0155	-0.0151	-0.0161	-0.0158	REPLACED WELL W-3S IN PHASE 2 WITH WELL W-3SR			
W-3SR/TW-83A	INSTALLED W-3SR IN PHASE 2 TO REPLACE W-3S						-0.0150	-0.0135	-0.0138
W-4S/GW-2	-0.1414	-0.1485	-0.1286	-0.1377	-0.1345		-0.1412	-0.1347	-0.1300
GW-1/W-5D	-0.0703	-0.0733	-0.0598	-0.0677	-0.0647	-0.0767	-0.0716	-0.0635	-0.0600
W-6S/W-6D	-0.1262	-0.1230	-0.1097	-0.1121	-0.1117		-0.1333	-0.1159	-0.1209
W-7S/W-7D	-0.0232	-0.0226	-0.0199	-0.0246	-0.0206	-0.0221	-0.0204	-0.0175	-0.0167
W-8S/W-8D	-0.0936	-0.1069	-0.1024	-0.0969	-0.1055	-0.1216	-0.1193	-0.1141	-0.0981
W-11S/W-11D	INSTALLED W-11D IN PHASE 2					-0.0272	-0.0263	-0.0210	-0.0199
GW-7/W-18I	INSTALLED W-18I IN PHASE 2					-0.0498	-0.0469	-0.0395	-0.0329
W-26S/W-26I	INSTALLED WELL NEST W-26S/W-26I/W-26D IN PHASE 2					0.0046	0.0057		0.0059
W-26I/W-26D						-0.0209	-0.0202		-0.0116
W-26S/W-2SD						-0.0088	-0.0079		-0.0032
W-27S/W-27I	INSTALLED WELL NEST W-27S/W-27I/W-27D IN PHASE 2					-0.0195	-0.0177	-0.0163	-0.0112
W-27I/W-27D						-0.0217	-0.0011	0.0002	0.0009
W-27S/W-27D						-0.0203	-0.0108	-0.0103	-0.0068
W-28S/W-28D	INSTALLED WELL NEST W-28S/W-28D IN PHASE 2					-0.0042	-0.0042	-0.0035	-0.0036
W-29S/W-29D	INSTALLED WELL NEST W-29S/W-29D IN PHASE 2					-0.0992	-0.0957	-0.0891	-0.0744
W-30S/W-30D	INSTALLED WELL NEST W-30S/W-30D IN PHASE 2					-0.0163	-0.0162	-0.0137	-0.0123
W-34S/W-34I	INSTALLED WELL NEST W-34S/W-34I IN PHASE 2					-0.0253	-0.0039	-0.0033	-0.0039
W-35S/W-35I	INSTALLED WELL NEST W-35S/W-35I IN PHASE 2					-0.0017	-0.0017	-0.0012	-0.0007
W-36S/W-36D	INSTALLED WELL NEST W-36S/W-36D IN PHASE 2					-0.0138	-0.0122		-0.0099
MW-1A/MW-1B	-0.1749	-0.1837	-0.1683	-0.1765	-0.1628		-0.1953	-0.1965	-0.1742
MW-1A/MW-1C	-0.0502	-0.0507	-0.0475	-0.0585	-0.0433		-0.0542	-0.0606	-0.0482
MW-1B/MW-1C	-0.0054	-0.0030	-0.0045	-0.0164	-0.0009		-0.0048	-0.0133	-0.0042
MW-2B/MW-2C	-0.0125	-0.0146	-0.0111	-0.0126	-0.0104		-0.0083	-0.0130	-0.0102
MW-3A/MW-3C	-0.0313	-0.0355	-0.0282	-0.0348	-0.0300		-0.0314	-0.0273	-0.0256

NOTE: POSITIVE VALUES ARE UPWARD AND NEGATIVE  
VALUES ARE DOWNWARD VERTICAL GRADIENTS

TEM/v1r/MAO/RSL  
[ndj-401-29g]  
12686

Table 5-4  
In-Situ Hydraulic Conductivity Results  
Sturgis Well Field RI/FS  
Sturgis, Michigan

<u>Well</u>	<u>Static Water Level</u>	<u>Well Penetration Depth</u>	<u>Screened Formation</u>	<u>Hydraulic Conductivity (cm/s)</u>
W1S	41.25	8.75	SP	$1.3 \times 10^{-2}$
W1D	41.20	51.00	SP-SM	$1.7 \times 10^{-2}$
W2S	56.98	5.50	SP	$8.7 \times 10^{-3}$
W2I	53.67	50.00	SP	$3.5 \times 10^{-2}$
W3S	47.82	8.50	SPSM (w/trace clay)	$6.6 \times 10^{-4}$
TW83A	48.30	30.00	Fine to medium sand (SP)	$3.0 \times 10^{-3}$
W4S	36.08	6.00	SP	$1.6 \times 10^{-2}$
GW2	44.63	43.38	Coarse sand and gravel (SW)	$5.1 \times 10^{-2}$
GW1	44.72	26.00	Sand and gravel (SP)	$2.3 \times 10^{-2}$
W5D	43.13	34.40	SP-SM	$4.4 \times 10^{-3}$
W5DD	42.31	18.90	ML-CL	$8.4 \times 10^{-6}$
W6S	35.06	19.80	SM and CL	$1.3 \times 10^{-4}$
W6D	45.64	22.50	SM	$2.6 \times 10^{-2}$
W7S	52.80	7.00	SP	$3.6 \times 10^{-3}$
W7D	55.57	35.50	SP-SM	$2.1 \times 10^{-2}$
W8D	46.39	54.00	SP	$2.5 \times 10^{-2}$
W9S	48.02	8.00	SP	$5.1 \times 10^{-3}$
W10S	44.66	8.74	SP	$1.1 \times 10^{-2}$
W11S	61.77	4.70	SP	$6.0 \times 10^{-3}$
W15S	52.72	4.98	SP	$8.3 \times 10^{-2}$
W18I	44.43	51.07	SP-SM	$1.5 \times 10^{-3}$
W20S	62.74	5.36	SP	$8.9 \times 10^{-2}$
W22S	60.79	5.31	SP	$1.2 \times 10^{-1}$
W26I	57.66	47.34	SP	$8.4 \times 10^{-3}$
W26D	58.94	5.50	SM	$1.6 \times 10^{-2}$
W28D	63.14	8.40	CL and SP-GP	$7.9 \times 10^{-3}$
W30D	56.45	7.30	CL and SP-GP	$3.7 \times 10^{-3}$
W32D	52.77	200.24	SP-GP	$1.3 \times 10^{-3}$
W34I	62.62	46.38	SP	$2.2 \times 10^{-2}$
W35S	54.90	9.70	SP	$1.9 \times 10^{-1}$
W35I	54.49	51.51	SP-SM	$1.2 \times 10^{-2}$
W36S	52.68	7.32	CL and SP	$4.5 \times 10^{-2}$
W36D	53.87	11.00	SP	$1.7 \times 10^{-2}$
W37I	57.59	40.41	SP	$1.3 \times 10^{-2}$
W39S	34.21	7.79	SP	$8.7 \times 10^{-2}$
W39D	36.70	68.00	SP-SM	$2.2 \times 10^{-3}$
W40S	54.13	8.87	SP	$1.6 \times 10^{-1}$
W40D	55.46	103.00	SP - GP	$1.4 \times 10^{-3}$
W41D	49.81	93.00	SP - GP	$1.4 \times 10^{-2}$
MW6	45.58	8.00	Coarse sand and gravel (SW)	$1.5 \times 10^{-2}$

MT/vlr/TEM/TAPB  
[vlr-400-27a]  
12686.70-MD

**Table 5-5**  
**Statistical Summary of In-Situ Hydraulic Conductivity Results**  
**Sturgis Well Field RI/FS**  
**Sturgis, Michigan**

<u>Aquifer</u>	<u>Geometric Mean (cm/s)</u>	<u>Number of Results</u>	<u>Upper 80% Confidence Interval (cm/s)</u>	<u>Lower 80% Confidence Interval (cm/s)</u>
Upper	$1.74 \times 10^{-2}$	19	$3 \times 10^{-2}$	$1 \times 10^{-2}$
Middle	$1.07 \times 10^{-2}$	6	$1.9 \times 10^{-2}$	$6 \times 10^{-3}$
Lower	$7.41 \times 10^{-3}$	14	$1.1 \times 10^{-2}$	$5 \times 10^{-3}$

TABLE 6-1  
SUMMARY OF ORGANIC QUALIFIER DEFINITIONS

Laboratory Qualifiers

- U The material was analyzed for, but not detected.
- J Indicates an estimated value. This flag is used either when estimating a concentration for tentatively identified compounds where a 1:1 response is assumed, or when the quality control criteria are not met.
- B This flag is used when the analyte is found in the associated blank as well as in the sample. It indicates possible blank contamination and warns the data user to take appropriate action. This flag must be used for a tentatively identified compound as well as for a positively identified target compound.
- C (For Pesticide/PCB data). The associated value was confirmed using dual column verification.
- E The compound was quantitated above the linear calibration range.
- D The compound was quantitated from an analysis at a secondary dilution factor.
- X The associated value was quantitated manually.
- I The tentatively identified compound is an isomeric-type of the compound reported.
- C The tentatively identified compound refers to a class of compounds.
- A The tentatively identified compound is an aldol-type compound.
- G DBC shift was greater than 2 percent. Samples were reanalyzed and matrix interference was confirmed. Coelutions of Dieldrin and 4, 4 DDE are present on the OV-1 column. Third column confirmation was not performed.

Data Validation Qualifiers

- U The material was analyzed for, but not detected. The associated numerical value is the sample quantitation limit.
- UJ The material was analyzed for, but not detected. The associated numerical value is an estimated quantity because quality control criteria were not met.
- J The associated numerical value is an estimated quantity.
- R The data are unusable (compound may or may not be present). Resampling and/or reanalysis is necessary for verification.

TABLE 6-2

SUMMARY OF INORGANIC QUALIFIER DEFINITIONS

Laboratory Qualifiers

- U The material was analyzed for, but was not detected.
- K The associated value was greater than or equal to the instrument detection limit, but less than the contract required detection limit.
- E Indicates the value reported is estimated due to the presence of an interference.
- M Duplicate injection precision for furnace analyses was not met.
- \* Duplicate analysis is not within control limits.
- + Correlation coefficient for the MSA is less than 0.995.
- S The associated value was determined by the method of standard additions.
- N Indicates the spike sample recovery is not within control limits.
- W Post-digestion spike for Furnace AA analysis is out of control limits (85-115%), while sample absorbance is less than 50% of the spike absorbance.

Data Validation Qualifiers

- U The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
- UJ Sample was analyzed, but not detected. The associated value is an estimated quantity because quality control criteria were not met.
- R The data are unusable (compound may or may not be present). Resampling and/or reanalysis is necessary for verification.
- J The associated numerical value is an estimated quantity because quality control criteria were not met.

TABLE 6-3

Examples of Conditions Which Require  
Estimation of Organics Analysis Data  
Sturgis Well Field RI/FS  
Sturgis, Michigan

1. If the contract-required time period from the time of sampling to the time of sample extraction or analysis (holding time) is exceeded.
2. If the instrument initial or continuing calibration criteria are not within U.S. EPA established limits.
3. If the recoveries of the sample surrogate standards do not meet U.S. EPA established criteria.
4. If the response of the sample internal standards do not meet U.S. EPA established criteria.
5. If the concentration of the compound exceeds the calibration range of the instrument.
6. If the concentration of the compound is below the contract-required quantitation limit.
7. If the compound is a Tentatively Identified Compound.

Table 6-4

**SUMMARY OF EXISTING WELL SAMPLE VOC ANALYSES - FIELD GC  
STURGIS WELL FIELD RI/FS  
STURGIS, MICHIGAN**

<u>Location</u>	<u>Date Sampled</u>	<u>TCE</u>	<u>PCE</u>	<u>1,2-DCE</u>	<u>1,1,1-TCA</u>	<u>Toluene</u>	<u>Benzene</u>	<u>Trihalomethanes</u>	<u>Total VOCs</u>
PW-2	09-SEP-87								N/D
PW-3	09-SEP-87	2.63							2.63
PW-4	09-SEP-87								N/D
PW-5	09-SEP-87								N/D
TW-83A	15-SEP-87								N/D
TW-84A	15-SEP-87								N/D
	15-SEP-87								N/D
R-1	11-SEP-87	BMDL	12						12
R-2	11-SEP-87								N/D
R-3	11-SEP-87	0.16							0.16
R-4	11-SEP-87	219	0.2	0.77	0.28				220.25
R-5	11-SEP-87								N/D
MW-1A	11-SEP-87							14.6	14.6
MW-1B	11-SEP-87							BMDL	BMDL
MW-1C	11-SEP-87								N/D
MW-2B	12-SEP-87								N/D
MW-2C	12-SEP-87								N/D
MW-3A	11-SEP-87								N/D
MW-3C	11-SEP-87								N/D
A-1	09-SEP-87	20							20
F-1	25-SEP-87	95.1		BMDL					95.1
MW-4	25-SEP-87								N/D
MW-6	25-SEP-87								N/D
GW-1	15-SEP-87		1.22						1.22
GW-1	25-SEP-87		1.19						1.19
GW-2	25-SEP-87								N/D
GW-3	09-SEP-87					19.5			19.5
GW-4	15-SEP-87					BMDL	3.56		3.56
GW-7	12-SEP-87	0.92							0.92
GW-8	14-SEP-87		3.24						N/D
TW-84A	14-SEP-87								N/D
	14-SEP-87								N/D

NOTE: N/D = VOCs not detected in sample

BMDL = VOCs were detected in sample in concentrations below method detection limit  
Concentrations are in ug/L

TEM/ndj/RSL  
[ndj-401-291]  
12686.00-MD

Table 6-5

Summary of Groundwater VOC Analysis During Drilling  
Sturgis Well Field RI/FS  
Sturgis, Michigan

<u>LOCATION</u>	<u>DEPTH</u>	<u>TCE</u>	<u>PCE</u>	<u>DCE</u>	<u>1,1,1-TCA</u>	<u>1,1-DCA</u>	<u>BETX</u>	<u>THMs</u>	<u>TOTAL VOCs</u>
W-1S	49	172	308						480
W-1S	49	281	2.19						283
W-1D	75	236	BMDL						236
W-1D	101								N/D
W-2S	62								N/D
W-2D	60								N/D
W-2D	70	2.75							2.75
W-2D	80	67.4							67.4
W-2D	90	122							122
W-2D	100	1300							1300
W-2D	110	1110							1110
W-2D	120	956							956
W-2D	130	592							592
W-2D	140	408		BMDL					408
W-2D	145	364							364
W-2DR	157	149	BMDL	BMDL					149
W-2DR	168	153							153
W-2DR	177	391							391
W-2DR	197	1510							1510
W-2DR	217	13600							13600
W-2DR	237	528							528
W-2DR	257	2.70							2.70
W-3S	54	11.2	BMDL						11.2
W-5D	45		BMDL				2.53		2.53
W-5D	52		BMDL				6.53		6.53
W-5D	60		1.31						1.31
W-5D	105	BMDL	7.72		BMDL	BMDL			7.72
W-5D	115					BMDL			BMDL
W-5DD	150								N/E
W-5DD	197								N/E
W-5DD	250								N/E
W-6S	48								N/E
W-6D	114								N/E
W-6D	132								N/E
W-6D	140								N/E
W-7S	57	BMDL			1.29				1.29
W-7D	51								N/E
W-7D	74				BMDL				BMDL
W-7D	83						BMDL		BMDL
W-7D	142	BMDL	2.90						2.90
W-7D	165	1.65							1.65
W-7D	165								BMDL



**Table 6-5**  
(Continued)

<u>LOCATION</u>	<u>DEPTH</u>	<u>TCE</u>	<u>PCE</u>	<u>DCE</u>	<u>1,1,1-TCA</u>	<u>1,1-DCA</u>	<u>BETX</u>	<u>THMs</u>	<u>TOTAL VOCs</u>
W-8S	49								N/D
W-8D	82								N/D
W-8D	120								N/D
W-8D	132								N/D
W-9S	56								N/D
W-10S	53	63.6	10.4	1.95					76.0
W-11S	65	54.1	73.4						128
W-11S	70	56.7	1.74				BMDL		58.4
W-11D	74.5								N/D
W-11D	87								N/D
W-11D	97						1.07		1.07
W-11D	107	BMDL (B)							BMDL
W-11D	110	BMDL (B)							BMDL
W-11D	148								N/D
W-12S	64	BMDL	BMDL		BMDL		BMDL		BMDL
W-13S	64						BMDL (B)		BMDL
W-14S	64	BMDL	15.1			BMDL	BMDL		15.1
W-16S	56	5.70							5.70
W-17S	54	42.7	BMDL						42.7
W-19S	49	230	BMDL	3.43	BMDL				233
W-20S	67	20.2	BMDL						20.2
W-21S	65	2.35							2.35
W-22S	65	10.4							10.4
W-23S	65	19200	69.0	9.89	5.07				19300
W-24S	68	102							102
W-25S	68	21.1	1.71						22.8
W-26S	66	18600	BMDL (B)	6.80	9.30	5.80	2.60		18600
W-26D	78	7550							7550
W-26D	88	320							320
W-26D	98	2.00							2.00
W-26D	108	7.00							7.00
W-26D	138		BMDL (B)	BMDL (B)					BMDL
W-26D	148		BMDL (B)						BMDL
W-27S	50								N/D
W-27D	57	BMDL							BMDL
W-27D	67	BMDL (B)	BMDL (B)						BMDL
W-27D	77						BMDL (B)		BMDL
W-27D	87	4.90							4.90
W-27D	97						BMDL (B)		BMDL
W-27D	107				BMDL				BMDL
W-27D	117								N/D
W-27D	127	67.0							67.0
W-27D	137						BMDL		BMDL
W-27D	155	8.00	BMDL						8.00
W-27D	167	7.80	BMDL	BMDL					7.80
W-27D	171	BMDL	BMDL	BMDL					BMDL
W-27D	177								N/D
W-27D	198								N/D

Table 6-5  
(Continued)

LOCATION	DEPTH	TCE	PCE	DCE	1,1,1-TCA	1,1-DCA	BETX	THMs	TOTAL VOCs
W-28S	69								N/D
W-28D	80	BMDL							BMDL
W-28D	90	BMDL					BMDL (B)		BMDL
W-28D	100	BMDL					BMDL (B)		BMDL
W-28D	110						BMDL (B)		BMDL
W-28D	120						BMDL (B)		BMDL
W-29S	46		BMDL (B)				BMDL		BMDL
W-29D	77								N/D
W-29D	117						BMDL (B)		BMDL
W-29D	128						BMDL (B)		BMDL
W-29D	138								N/D
W-30S	64	BMDL			BMDL				BMDL
W-30D	67					BMDL			BMDL
W-30D	77								N/D
W-30D	87								N/D
W-30D	97		BMDL (B)						BMDL
W-30D	149								N/D
W-30D	154	BMDL (B)							BMDL
W-30D	159	1.00							1.00
W-31S	49								N/D
W-32S	56				1.10				1.10
W-32D	217	60.1					BMDL		60.1
W-32D	237	1020		1.52					1020
W-32D	257	3130	BMDL						3130
W-34S	68	13500	BMDL	BMDL			BMDL (B)		13500
W-34I	80	6550	BMDL				BMDL		6550
W-34I	90	3660	BMDL				BMDL (B)		3660
W-34I	100	1840	BMDL				BMDL (B)		1840
W-35S	64.5	133							133
W-35I	70	98.4							98.4
W-35I	80	193							193
W-35I	90	165							165
W-35I	99	191							191
W-36D	70								N/D
W-36D	80								N/C
W-36D	100								N/C
W-36D	107								N/C
W-36D	158								N/C
W-37I	70						BMDL		BMDL
W-37I	80						BMDL		BMDL
W-37I	90	2.27	1.37				BMDL		3.64
W-37I	100	2.65	1.14				BMDL		3.79
W-39S	41.5								N/C
W-40S	63.5								N/C
W-40D	150						1.63		1.63
W-40D	177								N/C
W-40D	197								N/C
W-40D	217								N/C
W-40D	237								N/C
W-40D	254								N/C

**Table 6-5**  
(Continued)

<u>LOCATION</u>	<u>DEPTH</u>	<u>TCE</u>	<u>PCE</u>	<u>DCE</u>	<u>1,1,1-TCA</u>	<u>1,1-DCA</u>	<u>BETX</u>	<u>THMs</u>	<u>TOTAL VOCs</u>
W-41S	49.6								N/D
W-41D	117	.	7.25		1.69				8.94
W-41D	137								N/D
W-41D	157								N/D
W-41D	177	13.8	32.9	BMDL					46.7
W-41D	197	6.02	BMDL						6.02
W-41D	237	330	77						407
W-41D	246	968	116						1084

NOTE: N/D = VOCs not detected in sample  
 BMDL = VOCs detected in the sample at concentrations below method detection limit.  
 Concentrations are in ug/L

**TABLE 6-6**  
**SUMMARY OF SOIL VOCs DETECTED DURING DRILLING - FIELD GC**  
**STURGIS WELL FIELD RI/FS**  
**STURGIS, MICHIGAN**

<u>Sample Location</u>	<u>Depth</u>	<u>TCE</u>	<u>PCE</u>	<u>1,1-DCE</u>	<u>1,2-DCE</u>	<u>1,1,1-TCA</u>	<u>1,2-DCA</u>	<u>BETX</u>	<u>MeCl2</u>	<u>Total VOCs</u>
W-2S	5		1.08							1.08
W-2S DUP	5	BMDL		BMDL						BMDL
W-2S	10	BMDL		1.19						1.19
W-2S	20			1.03						1.03
W-2S	30	BMDL								BMDL
W-6S	6				2.36	BMDL	4.37	10.4		17.1
W-6D	17	BMDL								BMDL
W-6D	27	BMDL	2.07							2.07
W-8S	5		3.67							3.67
W-8S	10		1.63							1.63
W-8S	15		4.35							4.35
W-8S	20		1.29							1.29
W-9S	1	3.75	924			2.19		51.7	2.05	984
W-9S	5	BMDL	26.8							26.8
W-10S	1	31.8	518							550
W-10S	5	10.5	214							225
W-10S	10	6.9	133							140
W-10S	20	9.6	230							240
W-10S	25	13	228							241
W-10S	30	5.26	485							490
W-11S	1	926	13700		248	11.2				14900
W-11S	5	22	678		3.4	BMDL				703
W-11S	10	9.72	120							130
W-11S	15	19.8	300		2.1					322
W-11S	20	27.5	131							159
W-11S	25	61.1	53.4							115
W-11S DUP	25	50.6	50							101
W-11S	30	69.4	39.9							109
W-11S	35	190	54.4							244
W-11S	40.5	126	126							252
W-11S	50	107	12.9							120
W-11S	60	62	49.7							112
W-18S	10	BMDL								BMDL
W-18S	15	3.49								3.49
W-18S	20	3.42								3.42
W-18S DUP	20	3.91								3.91
W-18S	25	4.61								4.61
W-18S	30	10.3								10.3
W-18S	40	10.1								10.1
W-20S	5	BMDL								BMDL
W-20S	10	3.48								3.48
W-20S	15	5.54								5.54
W-20S	20	9.35								9.35
W-20S	25	4.88								4.88
W-20S	30	14.4								14.4
W-20S	40	18.7								18.7
W-20S	50	25.6								25.6
W-20S DUP	50	15.7								15.7
W-21S	50	BMDL								BMDL
W-23S	5	35.4	BMDL							35.4
W-23S	15	103	3.30		4.74					111
W-23S	25	170	BMDL							170
W-23S	30	540	33.1							573
W-23S	40	958	BMDL							958
W-23S	50	5950	176							6130
W-22S	10	4.32								4.32
W-22S	15	4.00								4.00
W-22S	20	4.10								4.10
W-22S	25	5.26	BMDL							5.26
W-22S	30	4.67								4.67
W-22S	40	13.6	BMDL							13.6
W-22S DUP	40	17.9								17.9
W-22S	50	12.8								12.8

TABLE 6-6  
(Continued)

Sample Location	Depth	TCE	PCE	1,1-DCE	1,2-DCE	1,1,1-TCA	1,2-DCA	BETX	MeC12	Total VOCs
W-24S	5	10.2	16.4							26.6
W-24S	10	15.8	22.3							38.1
W-24S	15	28.1	17.2							45.3
W-24S	20	64.0	24.2							88.2
W-24S	25	72.6	16.9							89.5
W-24S	30	100	14.0							114
W-24S	40	116	BMDL							116
W-24S DUP	40	110	BMDL							110
W-24S	50	167								167
W-30S DUP	50							BMDL		BMDL
W-13S	25							BMDL		BMDL
W-13S	30							BMDL		BMDL
W-13S	40							BMDL		BMDL
W-13S DUP	40							BMDL		BMDL
W-13S	50									BMDL
W-16S	20		BMDL(B)							BMDL
W-16S	30		BMDL(B)							BMDL
W-16S	40	45.9								45.9
W-16S DUP	40	33.8								33.8
W-14S	15		BMDL(B)							BMDL
W-14S	20		3.47					BMDL		3.47
W-14S	25		BMDL							BMDL
W-14S	30		4.26							4.26
W-14S	40		4.00							4.00
W-14S DUP	40		4.16							4.16
W-32S	5		BMDL							BMDL
W-32S	10		4.06							4.06
W-32S	15		BMDL							BMDL
W-32S	20		BMDL							BMDL
W-32S	25		BMDL							BMDL
W-32S	30		BMDL							BMDL
W-32S DUP	30		BMDL							BMDL
W-32S	40		BMDL							BMDL
W-12S	5		BMDL					BMDL(B)	BMDL(B)	BMDL
W-12S	10		BMDL					BMDL(B)	BMDL(B)	BMDL
W-12S	15							BMDL(B)	BMDL(B)	BMDL
W-12S	20							BMDL(B)	BMDL(B)	BMDL
W-12S	25							BMDL(B)	BMDL(B)	BMDL
W-12S	30							BMDL(B)	BMDL(B)	BMDL
W-12S	40							BMDL(B)	BMDL(B)	BMDL
W-17S	15		12.3							12.3
W-17S	20	BMDL	17.4							17.4
W-17S	25	BMDL	26.4					BMDL		26.4
W-17S	30	BMDL	21.6							21.6
W-17S	40		8.40					BMDL		8.40
W-26S	5	BMDL	BMDL(B)					BMDL(B)		BMDL
W-26S	10	BMDL								BMDL
W-26S	15	15.3								15.3
W-26S	20	10.5						BMDL(B)		10.5
W-26S	25	38.4								38.4
W-26S	30	39.0						BMDL(B)		39.0
W-26S	40	127								127
W-26S	50	154	BMDL(B)							154
W-27S	20		BMDL(B)					BMDL		BMDL
W-27S	25							7.80		7.80
SB-02	2.5	109	4.49					51.5		165
SB-02	5	7.20						8.61		15.8
SB-02	7	28.4						6.08		34.5
SB-02	9	32.8						BMDL(B)		32.8
SB-02	11	46.6						BMDL(B)		46.6
SB-02 DUP	11	47.0						BMDL(B)		47.0
SB-02	15	69.5	BMDL					BMDL		69.5
SB-02	20	63.0	BMDL					BMDL		63.0
SB-02	25	47.7						BMDL		47.7
SB-02	30	139	BMDL					BMDL		139
SB-03	2	8.02						BMDL(B)		8.02
SB-03 DUP	2	12.2						BMDL(B)		12.2
SB-03	5	24.0						BMDL(B)		24
SB-03	9	34.2	BMDL					BMDL(B)		34.2
SB-03	15	107	BMDL					BMDL(B)		107

TABLE 6-6  
(Continued)

Sample Location	Depth	TCE	PCE	1,1-DCE	1,2-DCE	1,1,1-TCA	1,2-DCA	BETX	MeCl2	Total VOCs
SB-04	2.5	207	BMDL					BMDL(B)		207
SB-04	2.5	273						BMDL(B)		273
SB-04 DUP	2.5	286						BMDL(B)		286
SB-04	5	26.2						BMDL(B)		26.2
SB-04	7.5	10.1								10.1
SB-04	10	17.5								17.5
SB-04	15	25.4						BMDL(B)		25.4
SB-06	2.5	173000	4200					BMDL(B)		177000
SB-06	5	121000	BMDL					BMDL(B)		121000
SB-06	5	10300	345					BMDL(B)		10600
SB-06	7.5	813	BMDL					BMDL(B)		813
SB-06	10	681	BMDL					BMDL(B)		681
SB-06	15	993	BMDL					BMDL(B)		993
SB-06 DUP	15	1698	BMDL					BMDL(B)		1700
SB-06	20	2420	BMDL					BMDL(B)		2420
SB-01R	2.5	BMDL	BMDL(B)							BMDL
SB-01R	5	45.6	BMDL(B)	5.40						51.0
SB-01R	7.5	105	BMDL(B)	8.70						114
SB-01R	10	106	BMDL(B)	5.40						111
SB-01R DUP	10	131	BMDL(B)	6.30						137
SB-01R	15	175	BMDL	BMDL				BMDL(B)		175
SB-01R DUP	15	83.1	BMDL	BMDL				BMDL(B)		83.1
SB-01R	20	305	BMDL	BMDL				BMDL(B)		305
SB-01R	25	1176	BMDL	7.20				BMDL(B)		1180
SB-01R	30	1480	30.6	BMDL				BMDL(B)		1510
SB-05	2.5	12.6	BMDL					BMDL(B)		12.6
SB-05	5	BMDL	BMDL					BMDL(B)		BMDL
SB-05	7.5	42.6	BMDL					BMDL(B)		42.6
SB-05	10	27.3	BMDL	BMDL				BMDL(B)		27.3
SB-05	15	41.4	BMDL					BMDL(B)		41.4
SB-07	2.5	630	7.5(B)		7.20					645
SB-07	5	178	BMDL(B)							178
SB-07	20	1218	BMDL(B)							1218
SB-08	2.5	9.00	BMDL(B)							9
SB-08	5	72.6	BMDL(B)							72.6
SB-08	7.5	96.6	BMDL(B)							96.6
SB-08	10	196	BMDL(B)							196
SB-08	15	702	BMDL(B)							702
SB-08	20	390	BMDL(B)							390
SB-08 DUP	20	144	BMDL(B)							144
SB-08	25	927	BMDL(B)							927
SB-08	30	1914	33(B)							1947
W-181	15	BMDL								BMDL
W-181	20	4.00								4.00
W-181	25	4.00								4.00
W-181	30	3.00								3.00
W-181	50	BMDL								BMDL
W-19S	5	14.3								14.3
W-19S	10	136			BMDL					136
W-19S	15	119								119
W-19S	20	64.8								64.8
W-19S	25	93.9								93.9
W-19S	30	159								159
W-19S DUP	30	114								114
SB-09	2.5	7.77								7.77
SB-09	5	4.98								4.98
SB-09	10	3.06								3.06
SB-09	15	6.15								6.15
SB-09	20	21.7								21.7
SB-09	25	14.5								14.5
SB-09	30	43.2								43.2
SB-09 DUP	30	36.0								36.0
SB-10	1.5	BMDL								BMDL
SB-10	4.5	5.11								5.11
SB-10	10	14.5								14.5
SB-10	15	27.9								27.9
SB-10	20	100	BMDL							100
SB-10	25	62.8	BMDL							62.8
SB-10 DUP	25	66.1	BMDL							66.1
SB-10	30	44.4								44.4

TABLE 6-6  
(Continued)

Sample Location	Depth	TCE	PCE	1,1-DCE	1,2-DCE	1,1,1-TCA	1,2-DCA	BETX	MeCl2	Total VOCs
SB-11	1.5	5.37	15.4							20.8
SB-11	4.5	10.4	27.9							38.3
SB-11	10	51.2	148							199
SB-11	15	23.5	21.1							44.6
SB-11	20	68.6	47.7							116
SB-11	25	79.2	12.8							92.0
SB-11	30	70.4	9.31							79.7
SB-11 DUP	30	114	12.2							126
SB-12	2	28.4								28.4
SB-12	5	8.67								8.67
SB-12	10	BMDL						BMDL		BMDL
SB-12	15	BMDL						BMDL		BMDL
SB-12	20	3.18								3.18
SB-12	25	BMDL								BMDL
SB-12 DUP	25	BMDL								BMDL
SB-12	30	3.12								3.12
SB-13	1.5	4.57								4.57
SB-13	5	BMDL								BMDL
SB-13	10	10.4								10.4
SB-13	15	27.8	BMDL							27.8
SB-13	20	46.1	BMDL							46.1
SB-13	25	103	BMDL							103
SB-13	30	183	BMDL							183
SB-13	30	32.5								32.5
SB-13 DUP	30	60.8								60.8
W-33S	15	BMDL								BMDL
W-33S	25							BMDL		BMDL
W-33S	30	BMDL								BMDL
W-33S	40	3.67								3.67
W-33S DUP	40	4.74								4.74
SB-14	3.5		5.66							5.66
SB-14	6	BMDL	23.0							23.0
SB-14	10	BMDL	45.7							45.7
SB-14	15	BMDL	29.0							29.0
SB-14	20	BMDL	29.0							29.0
SB-14	25	3.00	40.3							43.3
SB-14	30	BMDL	39.0							39.0
SB-15	1.5	BMDL							14.0	14.0
SB-15	25							BMDL		BMDL
SB-15	30							BMDL		BMDL
W-35S	5	BMDL								BMDL
W-35S	10	BMDL								BMDL
W-35S	15	BMDL								BMDL
W-35S	20	BMDL								BMDL
W-35S	25	BMDL								BMDL
W-35S	30	BMDL								BMDL
W-35S	40	5.36								5.36
W-35S DUP	40	4.49								4.49
W-35S	50	4.30								4.30
W-25S	40	BMDL								BMDL
W-25S	50	3.91								3.91
W-40S	20	3.09								3.09
W-40S	25	3.18								3.18
W-40S	30	3.21								3.21
W-40S	35	BMDL								BMDL
W-40S	50	BMDL								BMDL
W-40S	60	BMDL								BMDL
W-41S	5	BMDL								BMDL
W-41S	10	BMDL								BMDL
W-42S	5	759	48.0		3.34					810
W-42S	10	572	BMDL							572
W-42S	15	160	21.8							182
W-42S	20	663	63.6							727
W-42S	25	264	BMDL							264
W-42S	30	939	61.5							1000
W-42S	35	1110	64.5							1180
W-42S	40	1140	64.5							1210
W-42S	45	1160	85.2							1250
W-42S	50	954	122							1080
W-42S	55	351	36.6				BMDL			388
W-42S	60	1560	BMDL							1560
W-42S	2.5	2810	1090		37.5					3940

TABLE 6-6  
(Continued)

Sample Location	Depth	TCE	PCE	1,1-DCE	1,2-DCE	1,1,1-TCA	1,2-DCA	BETX	MeCl2	Total VOCs
SB-18	2	411								411
SB-18 DUP	6	279								279
SB-18	6	282								282
SB-18	10	208								208
SB-18 DUP	10	207			BMDL					207
SB-18	15	1230	BMDL							1230
SB-18	20	774								774
SB-18	25	1310	BMDL							1310
SB-18	30	1220	BMDL							1220
SB-19	2	BMDL								BMDL
SB-19	4	6.72								6.72
SB-19	6	65.4								65.4
SB-19 DUP	6	81.9								81.9
SB-19	10	147	BMDL							147
SB-19	15	420								420
SB-20	2	207								207
SB-20	4	70.8								70.8
SB-20	6	345								345
SB-20 DUP	6	357								357
SB-20	10	642								642
SB-20	15	1040								1040
SB-20	20	1040								1040
SB-20	25	1240	BMDL						BMDL	1240
SB-20	30	1240								1240
SB-21	2	146								146
SB-21	4	62.4	BMDL							62.4
SB-21 DUP	4	52.5								52.5
SB-21	6	130								130
SB-21	10	186								186
SB-21	15	216								216
SB-21	20	148								148
SB-21 DUP	20	432								432
SB-21	25	828								828
SB-21	30	780								780

NOTE: BMDL = VOCs detected in sample at concentrations below method det  
(B) = Analyte detected in blank  
DUP = Duplicate analytical sample  
BETX = Total of benzene, ethyl benzene, toluene and xylenes  
MeCl2 = Methylene chloride  
Concentrations are in ug/kg

TEM/vlr/BJC  
[ndj-401-29k]  
12686.00-MD



TABLE 7-1

Summary of CLP Chemical Analyses of Soil Boring Samples(a)  
Sturgis Well Field RI/FS  
Sturgis, Michigan

Parameters	CONCENTRATION			Number Samples With Positive Detection
	Maximum	Minimum	Geometric Mean	
Volatile Organic Chemicals (ug/kg)				
Chloromethane	8.0	6.0	6.9	3
Bromomethane	5.0	5.0	5.0	1
Vinyl Chloride	6.0	6.0	6.0	1
Methylene Chloride	360.0	3.0	12.9	36
Acetone	7800.0	5.0	27.6	40
Total 1,2-Dichloroethene	1200.0	5.0	27.6	4
Chloroform	42.0	2.0	4.1	17
2-Butanone	45000.0	3.0	22.9	27
1,1,1-Trichloroethane	10.0	3.0	5.0	13
Carbon Tetrachloride	9.0	9.0	9.0	1
Trichloroethene	99000.0	2.0	40.2	70
Benzene	4.0	4.0	4.0	1
Tetrachloroethene	260000.0	1.0	40.5	38
Toluene	250.0	1.0	17.4	94
Chlorobenzene	19.0	2.0	5.8	14
Ethylbenzene	3.0	3.0	3.0	1
Total Xylenes	6.0	6.0	6.0	1
Semivolatile Organic Chemicals (ug/kg)				
Benzoic acid	27.0	27.0	27.0	1
1,2,4-Trichlorobenzene	25.0	25.0	25.0	1
Naphthalene*	290.0	63.0	145.9	3
2-Methylnaphthalene*	420.0	16.0	121.0	4
Acenaphthylene*	360.0	110.0	199.0	2
Dibenzofuran*	180.0	130.0	158.4	3
Fluorene*	220.0	220.0	220.0	1
Pentachlorophenol	200.0	200.0	200.0	1
Phenanthrene*	3600.0	14.0	277.3	10
Anthracene*	760.0	52.0	131.0	6
Di-n-butylphthalate	150.0	63.0	97.2	2
Fluoranthene*	5200.0	68.0	330.0	10
Pyrene*	8100.0	78.0	366.1	10
Butylbenzylphthalate	500.0	16.0	136.5	5
Benzo(a)anthracene*	5000.0	50.0	303.4	8
Chrysene*	4000.0	49.0	297.8	9
bis(2-Ethylhexyl)phthalate	700.0	290.0	388.3	4
Di-n-octylphthalate	150.0	150.0	150.0	1
Benzo(b)fluoranthene*	5100.0	47.0	320.6	9
Benzo(k)fluoranthene*	3500.0	73.0	280.8	5
Benzo(a)pyrene*	5100.0	61.0	255.0	10

TABLE 7-1  
(continued)

Parameters	CONCENTRATION			Number Samples With Positive Detection
	Maximum	Minimum	Geometric Mean	
Indeno(1,2,3-cd)pyrene*	3000.0	49.0	186.8	6
Dibenz(a,h)anthracene*	1100.0	81.0	237.3	3
Benzo(g,h,i)perylene*	1600.0	56.0	173.4	7
Pesticides/PCBs (ug/kg)				
AROCLOR-1260	290.0	290.0	290.0	1
Metals (mg/kg)				
Aluminum	15600.0	1920.0	5494.1	55
Antimony	70.0	11.0	28.0	20
Arsenic	16.0	2.0	5.7	53
Barium	249.0	6.5	46.8	54
Beryllium	1.6	0.2	0.5	24
Cadmium	5.2	0.8	2.1	27
Calcium	101000.0	662.0	10108.7	53
Chromium, Total	62.8	3.4	12.1	52
Cobalt	13.2	2.9	5.0	46
Copper	2030.0	5.7	30.0	53
Iron	108000.0	5430.0	13556.8	55
Lead	167.0	4.2	17.4	55
Magnesium	21800.0	752.0	3682.8	55
Manganese	3800.0	160.0	509.9	55
Mercury	0.3	0.1	0.2	6
Nickel	69.4	4.7	11.8	51
Potassium	1280.0	268.0	495.2	45
Selenium	0.6	0.5	0.5	3
Silver	4.4	0.8	1.9	2
Sodium	11800.0	552.0	3636.0	4
Thallium	0.5	0.5	0.5	1
Vanadium	40.5	6.0	16.2	54
Zinc	2010.0	2.9	66.5	55
Cyanide, Total	188.0	1.5	10.5	7
Percent Solids	96.7	78.1	91.4	55

- (a) Positively detected samples refer to those quantified by the laboratory and exclude values considered to be laboratory and field contaminants. Refer to Appendix F to determine the total number of samples collected and the complete list of parameters analyzed. The asterisk indicates the compound belongs to the polycyclic aromatic hydrocarbon (PAH) class.

Table 7-2

Shallow Soil TCE and PCE Distributions  
at Kirsch Co. Plant No. 1  
Sturgis Well Field RI/FS  
Sturgis, Michigan

<u>Location</u>	<u>Depth (ft)</u>	<u>TCE (ug/kg)</u>	<u>PCE (ug/kg)</u>
SB-06	2.5	27,000	770
SB-06	20	120	ND
W11S	1	8,200	260,000
W11S	5	15	590
W42S	2.5	99,000	18,000
W42S	15	87	16

**Table 7-3**  
**Background Concentrations of Metals**  
**for Site Groundwater and Soil**

<u>Constituent</u>	<u>Range of Groundwater Concentrations (ug/L)</u>	<u>Soil Concentration (mg/kg)</u>
Aluminum	20U - 87	12,900
Antimony	30.7U	48
Arsenic	2U	8.7
Barium	30.2 - 75.9	153
Beryllium	0.83U	0.74
Cadmium	4.8U	2.9 (a)
Calcium	78,100 - 112,000	19,700 (b)
Chromium (total)	7.8U	19.8
Cobalt	31U	7.1
Copper	12U	38.5 (b)
Iron	22.3U - 87	18,100
Lead	1U - 1.7	34.9 (b)
Magnesium	24,500 - 34,500	4,340 (b)
Manganese	7.8 - 13	712
Mercury	0.2U	0.1U
Nickel	8.2U	17.3
Potassium	541 - 685	640
Selenium	1.6u - 1.7	1.0U
Silver	9.3U	0.82U
Sodium	2,410 - 24,900	327U
Thallium	2U	0.42U
Vanadium	36U	27
Zinc	12.8U - 1,590	101 (b)
Cyanide	10U	0.5U

Wells W11S and PW6 were considered representative of background groundwater quality for inorganic constituents of the shallow and deep aquifer, respectively. The range of concentrations presented in this table summarizes the analytical results of samples W11S-02, W11S-03 and PW6-04. The maximum value was used to represent background for the Site.

Background samples for soils were selected based on the absence of detectable chlorinated ethenes and ethanes. The concentration presented was derived using the analytical results of samples SB15-1.5, SB15-05, SB16-1.5, SB16-05, SB17-1.5, SB17-05, SB29-0.5 and SB31-0.5. The background concentrations usually are the mean concentration detected plus three standard deviations. This statistic was used when the coefficient variance (standard deviation divided by the mean) of the sample group was less than or equal to 0.5. The maximum analyte concentration was used to represent background when two or less analyte values were available (a) or when the coefficient of variance of the sample group exceeded 0.5 (b).

A value followed by a "U" indicates that the constituent was not detected above this quantity (i.e., the value represents the sample quantitation limit). When each background sample showed non-detectable levels, the highest sample quantitation is listed.

**Table 7-4**  
**Vertical Distribution of TCE and PCE in Soil SB11**  
**Sturgis Well Field RI/FS**  
**Sturgis, Michigan**

<u>Sample Depth</u> <u>(ft)</u>	<u>TCE</u> <u>(ug/kg)</u>	<u>PCE</u> <u>(ug/kg)</u>
1.5	3	24
4.5	160	630
10	120	500
15	ND	ND
20	9	8
25	9	7
30	13	ND

**Table 7-5**

**Vertical Distribution of TCE and PCE in Soil at Well W10S  
Sturgis Well Field RI/FS  
Sturgis, Michigan**

<u>Sample Depth (ft)</u>	<u>TCE (ug/kg)</u>	<u>PCE (ug/kg)</u>
1	ND	110
5	2	110
10	ND	ND
20	ND	3
25	ND	11
30	ND	23

MT/vlr/RSL  
[wptemp-400-29a]  
12686.70

Table 7-6

**Summary of CLP Chemical Analyses of Groundwater Samples(a)  
Sturgis Well Field RI/FS  
Sturgis, Michigan**

Parameter	Concentration		Geometric Mean	Number Samples With Positive Detection
	Maximum	Minimum		
VOLATILE ORGANIC CHEMICALS (ug/L)				
Acetone	5.0	3.0	3.9	5
1,1-Dichloroethane	2.0	2.0	2.0	1
Total 1,2-Dichloroethene	17.0	0.5	6.0	13
Chloroform	16.0	0.5	2.3	7
1,2-Dichloroethane	1.0	1.0	1.0	2
1,1,1-Trichloroethane	9.0	0.3	2.0	11
Bromodichloromethane	2.0	1.0	1.0	3
Trichloroethene	17,000.0	0.2	21.0	80
Dibromochloromethane	1.0	1.0	1.0	2
1,1,2-Trichloroethane	8.0	0.3	1.8	6
Benzene	2.0	0.2	0.9	3
4-Methyl-2-Pentanone	0.7	0.7	0.7	1
2-Hexanone	0.6	0.6	0.6	1
Tetrachloroethene	150.0	0.3	5.0	25
1,1,2,2-Tetrachloroethane	0.3	0.3	0.3	1
Trans-1,2-Dichloroethene	4.0	4.0	4.0	1
SEMIVOLATILE ORGANIC CHEMICALS (ug/L)				
Benzoic acid	4.0	4.0	4.0	1
bis(2-Ethylhexyl)phthalate	51.0	3.0	7.6	10
Di-n-octylphthalate	8.0	2.0	3.9	4
METALS (ug/L)				
Aluminum	106.0	20.5	43.6	18
Antimony	197.0	197.0	197.0	1
Arsenic	3.6	1.2	2.0	5
Barium	176.0	24.0	68.8	44
Beryllium	0.6	0.6	0.6	2
Cadmium	5.7	4.8	5.0	3
Calcium	190,000.0	37,000.0	91,597.4	212
Chromium, Total	19.0	5.5	12.4	3
Cobalt	6.9	6.9	6.9	1
Copper	9.6	8.0	8.7	2
Iron	1,970.0	18.0	50.3	32
Lead	15.3	1.0	2.2	10
Magnesium	117,000.0	2,540.0	27,248.5	212
Manganese	462.0	0.6	20.1	29
Mercury	0.3	0.2	0.2	2
Nickel	40.1	6.6	16.5	6

Table 7-6  
(Continued)

Parameter	Concentration			Number Samples With Positive Detection
	Maximum	Minimum	Geometric Mean	
Potassium	25,000.0	500.0	1,389.2	178
Selenium	5.3	1.1	2.3	15
Sodium	543,000.0	1,520.0	17,830.9	206
Thallium	1.1	1.1	1.1	1
Zinc	17,800.0	31.0	210.6	39
Cyanide, Total	247.0	10.4	31.1	8

**INDICATOR PARAMETERS (mg/L)**

Alkalinity	11,700.0	226.0	326.7	168
Chloride	972.0	0.9	34.8	165
Total Kjeldahl Nitrogen	18.0	0.1	0.5	98
Sulfate	185.0	3.3	37.6	167
Total Organic Carbon	80.2	0.6	3.9	21
Nitrate + Nitrite Nitrogen	540.0	0.1	3.1	150

- (a) Refer to Appendix E to determine the total number of samples collected and the complete list of parameters measured within each analysis group.



**Table 7-7**

**CLASSIFICATION OF DISSOLVED INORGANIC  
CONSTITUENTS IN NATURALLY OCCURRING GROUNDWATER  
(from Davis and DeWiest, 1966)**

**Major constituents (1.0 to 1000 mg/L)**

Bicarbonate alkalinity	Magnesium
Calcium	Sodium
Chloride	Sulfate

**Secondary constituents (0.01 to 10.0 mg/L)**

Iron	Potassium
Nitrate	

**Minor constituents (0.001 to 0.1 mg/L)**

Aluminum	Lead
Antimony	Manganese
Arsenic	Nickel
Barium	Phosphate
Cadmium	Selenium
Chromium	Vanadium
Cobalt	Zinc
Copper	

**Trace constituents (generally less than 0.0001 mg/L)**

Beryllium	Thallium
Silver	

TABLE 7-8

Field Observations  
Round 1 Sampling  
Sturgis Well Field RI/FS  
Sturgis, Michigan

<u>Groundwater Well #</u>	<u>pH</u>	<u>Specific Conductance at 25°C</u>	<u>Color</u>	<u>Odor</u>	<u>Turbidity</u>
GW	7.05	805	Clear	None	None
GW1 duplicate	7.26	814	Clear	None	None
GW2	7.22	719	Clear	None	None
GW3	7.21	921	Clear	None	Slight
GW4	6.92	1875	Clear	Fuel Oil	Slight
GW7	7.22	2120	Lt. Brown	None	Moderate
GW8	7.18	1100	Clear	None	None
MW1A	7.43	873	Lt. Brown	None	Slight
MW1B	7.43	463	Black	None	Moderate
MW1C	7.37	577	Lt. Brown	Swamp	Slight
MW1C duplicate	7.39	583	Lt. Brown	Swamp	Slight
MW2B	7.44	537	Clear	None	Slight
MW2C	7.30	558	Lt. Gray	None	Slight
MW3A	7.33	576	Clear	None	Slight
MW3C	7.19	500	Dk. Brown	None	Slight
TW83A	7.36	476	Clear	None	None
TW84A	7.00	633	Clear	None	None
TW84A duplicate	7.05	626	Clear	None	None
MW4	7.17	860	Clear	None	None
MW6	7.35	515	Lt. Brown	none	Slight

TABLE 7-8  
Field Observations  
Round 1 Sampling  
Sturgis Well Field RI/FS  
Sturgis, Michigan  
(continued)

<u>Groundwater Well #</u>	<u>pH</u>	<u>Specific Conductance at 25°C</u>	<u>Color</u>	<u>Odor</u>	<u>Turbidity</u>
<u>Pumping Wells</u>					
A1	7.02	918	Lt. Brown	None	None
PW2	7.00	545	Clear	None	None
PW3	7.15	652	Clear	None	None
PW3 duplicate	7.20	666	Clear	None	None
PW4	7.25	550	Clear	None	None
PW5	7.20	550	Clear	None	None
R1	7.42	600	Clear	None	None
R2	7.39	732	Clear	None	None
R3	7.41	662	Clear	None	None
R4	7.48	756	Clear	none	None
R5	7.34	488	Clear	None	None
PWF1	7.00	890	Clear	None	None
<u>Surface Water</u>					
W01	7.85	200	Lt. Green	None	Slight
W01 duplicate	7.86	200	Lt. Green	None	Slight
W02	7.98	566	Clear	None	Slight
W03	7.65	188	Clear	None	None
W04	7.50	9090	---	---	---
<u>Sample Blanks</u>					
SB01	6.05	17	Clear	None	None
SB02	7.33	<10	Clear	None	None
SB03	7.05	<10	Clear	None	None
SB04	7.33	<10	Clear	None	None

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[wptemp-402-90c]  
12686.70

TABLE 7-9  
Field Observations  
Round 2 Sampling  
Sturgis Well Field RI/FS  
Sturgis, Michigan

Groundwater Well #	pH	Specific Conductance at 25°C	Temperature °C	Color	Odor	Turbidity
F1	7.14	875	11	Clear	None	None
GW1	7.41	855	13	Clear	None	
GW2	7.27	800	12.5	Clear	None	None
GW3	7.31	786	10	Clear	None	None
GW4	6.95	1970	13	Grey	None	
GW7	7.32	2160	12	Tan	None	Slight
GW8	7.22	1080	13	Clear	None	
MW1C	7.60	602	14	Black	None	Moderate
MW1C duplicate	7.58	602	14	Black	None	Moderate
MW1A	7.62	1410	14	Black	None	Moderate
MW1B	7.59	474	13	Black	None	Moderate
MW2C	7.50	524	16	Lt. Brown	None	Slight
MW2B	7.55	553	13	Clear	None	None
MW3C	7.60	500	13	Black	None	Moderate
MW3A	7.51	579	13	Clear	None	None
MW4	7.39	938	15	Clear	None	None
MW6	7.66	528	11	Clear	None	
PW2 duplicate	7.25	588	17.5	Clear	None	None
PW2	7.36	595	17	Clear	None	None
PW3	7.34	714	17	Clear	None	None
PW4	7.48	548	17	Clear	None	None
PW5	7.38	571	17	Clear	None	None
R1	7.55	602	14	Clear	None	None
R2	7.60	769	14	Clear	None	None
R3	7.54	688	15	Clear	None	None
R4	7.43	732	16	Clear	None	None
R5	7.65	525	15	Clear	None	None
TW83A	7.42	526	14	Clear	None	
TW84A	7.37	643	10	Clear	None	None
TW84A duplicate	7.47	647	9	Clear	None	None
W1D	7.26	833	11	Clear	None	
W1S	7.32	890	11.5	Clear	None	None
W21		754	14.5	Clear	None	
W2S		1410	14	Brown	None	
W3S		1320	13	Brown	None	
W4S	7.25	772	14.5	Lt. Brown	None	Very Slight
W4S duplicate	7.23	762	15	Lt. Brown	None	Very Slight
W5D	7.36	765	9	Clear	None	
W6	7.48	641	14	Clear	None	
W6S	7.86	750	15	Brown	None	
W7S		513	14	Brown	None	
W7D		584	13.5	Clear	None	
W8D	7.59	667	14	Clear	None	
W8S	7.72	750	13	Brown	None	
W9S	7.43	812	15	Brown	None	
W10S		769	14	Brown	None	
W11S	7.37	705	14	Brown	None	

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[wptemp-402-90b]  
12686.70

TABLE 7-10

Field Observations  
Round 3 Sampling  
Sturgis Well Field RI/FS  
Sturgis, Michigan

Groundwater Well #	pH	Specific Conductance at 25°C	Temperature °C	Color	Odor	Turbidity
F-1	7.20	920	13	Clear	None	None
GW-1	7.15	805	13.5	Clear	None	None
GW-2	7.38	645	13	Clear	Slight H <sub>2</sub> S	None
GW-3	7.20	670	11.5	Clear	None	None
GW-7	6.94	2180	11	Clear	Slight Oil	Slight
GW-8	7.37	1010	11.5	Clear	None	None
MW-1A	7.27	545	14	Black	Septic	Moderate
MW-1B	7.42	460	14	Black	Septic	Very Turbid
MW-1C	7.37	540	12	Black	Slight Septic	Very Turbid
MW-2B	7.58	585	11	Clear	None	None
MW-2C	7.68	540	11	Slight Black	Rotten Eggs	Slight
MW-2C duplicate	7.74	540	11	Slight Black	Rotten Eggs	Slight
MW-3A	7.53	610	11	Clear	None	None
MW-3C	7.64	515	11	Clear	None	None
MW-4	7.32	770	16	Clear	None	None
MW-6	7.38	555	11	Clear	None	None
PW-3	7.30	610	13.5	Clear	None	None
PW-4	7.97	595	12	Clear	None	None
PW-4 duplicate	7.85	595	12	Clear	None	None
PW-5	7.40	605	12.5	Clear	None	None
R-1	7.42	670	13	Clear	None	None
R-2	7.54	660	13	Clear	None	None
R-3	7.49	665	12.5	Clear	None	None
R-4	7.29	845	15	Clear	None	None
R-5	7.63	615	12.5	Clear	None	None
TW-83A	7.51	520	10.5	Clear	None	None
TW-84A	7.29	635	12	Clear	None	None
TW-84A duplicate	7.30	635	12	Clear	None	None
W-01D	7.30	880	12	Clear	None	None
W-01S	7.07	875	11	Clear	None	None
W-02DR	7.25	775	10.5	Clear	None	None
W-02DR duplicate	7.26	775	10.5	Clear	None	None
W-02I	7.18	760	10.5	Clear	None	None
W-02S	7.42	795	9	Brown	None	Very Turbid
W-03SR	7.68	730	10	Brown	None	Very Turbid
W-04S	7.39	770	14	Brown	None	Very Turbid
W-05D	7.57	595	12	Light Black	Septic	Slight

TABLE 7-10

Field Observations  
Round 3 Sampling  
Sturgis Well Field RI/FS  
Sturgis, Michigan  
(continued)

Groundwater Well #	pH	Specific Conductance at 25°C	Temperature °C	Color	Odor	Turbidity
W-06D	7.48	635	12	Clear	None	None
W-06S	7.95	790	13	Brown	None	Moderate
W-07D	7.35	625	8.5	Clear	None	None
W-07D duplicate	7.48	635	8.5	Clear	None	None
W-07S	7.87	415	8	Brown	None	Very Turbid
W-08D	7.29	670	11.5	Clear	None	None
W-08S	7.80	760	12.5	Brown	None	Moderate
W-09S	7.40	1085	13	Light Brown	None	Moderate
W-10S	7.82	550	10.5	Brown	None	Moderate
W-11D	7.24	510	11	Clear	None	None
W-11D duplicate	7.41	510	10	Clear	None	None
W-11S	7.08	785	9.5	Brown	None	Very Turbid
W-12S	7.49	520	9	Brown	None	Very Turbid
W-13S	7.46	840	9.5	Clear	None	Slight
W-14S	7.50	520	10	Clear	None	None
W-15S	7.20	1100	10.5	Brown	None	Very Turbid
W-16S	7.69	565	10.5	Brown	None	Moderate
W-17S	6.93	930	11.5	Clear	Smokey	None
W-18I	7.21	1140	10	Clear	None	Moderate
W-19S	7.14	1805	11	Clear	None	None
W-20S	7.11	855	9	Brown	None	Very Turbid
W-21S	6.89	1250	10	Brown	None	Very Turbid
W-22S	7.11	1030	9	Brown	None	Very Turbid
W-23S	7.17	1110	11	Brown	None	Very Turbid
W-24S	7.15	955	8	Brown	Slight Solvent	Very Turbid
W-25S	7.22	1810	11	Brown	None	Moderate
W-26D	7.60	470	9	Clear	None	None
W-26I	7.79	610	9	Clear	None	None
W-26S	7.34	1430	10	Brown	None	Moderate
W-27D	7.08	1175	12	Clear	None	None
W-27D duplicate	7.11	1175	12	Clear	None	None
W-27I	6.98	1310	10.5	Clear	None	None
W-27S	7.31	820	11	Brown	None	Very Turbid
W-28D	7.40	475	12	Clear	None	None
W-28S	7.40	740	11.5	Brown	None	Moderate
W-29D	7.41	635	12	Clear	None	None
W-29D duplicate	7.47	635	12	Clear	None	None
W-29S	7.34	1340	12	Brown	None	Very Turbid
W-30D	7.31	645	10	Clear	None	None
W-30S	7.28	1585	10	Brown	None	Very Turbid
W-31S	7.52	530	11	Brown	None	Very Turbid
W-32S	6.82	1270	12.5	Clear	None	None
W-33S	7.16	1200	11.5	Brown	None	Moderate
W-34I	7.38	610	12	Slight Brown	None	Slight
W-34S	7.33	920	13	Brown	None	Moderate
W-35I	7.38	960	11.5	Clear	None	Slight
W-35I duplicate	7.39	960	11.5	Clear	None	Slight
W-35S	7.35	820	11.5	Brown	None	Moderate
W-36D	7.36	1600	9.5	Clear	None	None
W-36S	7.40	700	9	Brown	None	Very Turbid
W-37I	7.28	1050	12	Clear	None	Slight

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[wptemp-402-90a]  
12686.70

TABLE 7-11  
Field Observations  
Round 4 Sampling  
Sturgis Well Field RI/FS  
Sturgis, Michigan

Groundwater Well #	pH	Specific Conductance at 25°C	Temperature °C
PW2	7.06	1400	10
PW3	7.39	550	11.5
PW4	7.49	525	13
PW5	7.41	590	13
PW6	7.50	590	13
W2DR	7.20	745	14
W5DD	7.95	3335	14
W11D	7.52	490	16.0
W11S	7.22	810	12.0
W16S	7.49	625	15.0
W17S	7.03	885	14.5
W19S	7.14	845	16.5
W20S	7.27	845	16.5
W21S	7.22	1265	16.5
W22S	7.21	895	14.0
W23S	7.15	1100	16.0
W24S	7.23	1195	16.0
W25S	7.24	1810	15.0
W26I	7.45	625	15.0
W26D	7.38	480	13.5
W26S	7.22	1275	15.0
W34I	7.27	660	13.0
W34S	7.27	880	12.0
W34S duplicate	7.24	875	15.0
W32D	7.09	1340	16
W32D duplicate	7.13	1410	14
W35S	7.20	855	16
W35I	7.21	1025	14
W37I	7.12	1000	15
W39D	7.23	810	12
W39D duplicate	7.25	800	12.5
W39S	7.41	475	12
W40S	7.32	760	14.5
W40D	7.35	500	15
W41D	7.08	2050	14
W41S	7.33	770	14
W42S	7.11	1785	17
W42S duplicate	7.06	1785	17

MT/vlr/JV/RSL  
[wptemp-402-90]  
12686.70

Table 7-12

WATEQF OUTPUT FOR ROUND 1 INORGANIC ANALYTICAL RESULTS  
 AT WELL PW4  
 STURGIS WELL FIELD R1/FS  
 STURGIS, MICHIGAN

## INITIAL SOLUTION

TEMPERATURE = 15.00 DEGREES C      PH = 7.250      ANALYTICAL EPMCAT = 6.091      ANALYTICAL EPMAN = 6.406

## \*\*\*\*\* OXIDATION - REDUCTION \*\*\*\*\*

DISSOLVED OXYGEN = 0.000 MG/L  
 EH MEASURED WITH CALOMEL = 99.0000 VOLTS  
 MEASURED EH OF ZOBELL SOLUTION = 99.0000 VOLTS  
 CORRECTED EH = 0.0000 VOLTS  
 PE COMPUTED FROM CORRECTED EH = 0.000

FLAG    CORALK    PECALC    IDAVES  
 2       0       0       0

## \*\*\* TOTAL CONCENTRATIONS OF INPUT SPECIES \*\*\*

SPECIES		TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
CA	2	1.94704E-03	-2.7106	7.80000E+01
MG	2	9.46486E-04	-3.0239	2.30000E+01
NA	1	2.82869E-04	-3.5484	6.50000E+00
K	1	2.37953E-05	-4.6235	9.30000E-01
CL	-1	5.64396E-04	-3.2484	2.00000E+01
SO4	-2	3.33278E-04	-3.4772	3.20000E+01
HC03	-1	5.17805E-03	-2.2858	3.15800E+02

## \*\*\* CONVERGENCE ITERATIONS \*\*\*

ITERATION	S1-ANALC03	S2-S04TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	1.051892E-04	1.089790E-04	0.000000E+00	0.000000E+00	3.899913E-09
2	2.591871E-06	1.815555E-06	0.000000E+00	0.000000E+00	0.000000E+00
3	-1.415610E-07	-1.192093E-07	0.000000E+00	0.000000E+00	0.000000E+00

## \*\*\*\*\*DESCRIPTION OF SOLUTION \*\*\*\*\*

ANALYTICAL	COMPUTED	PH	ACTIVITY H2O = 0.9998
EPMCAT 6.091	5.870	7.250	PCO2 = 1.494548E-02
EPMAN 6.406	6.186		LOG PCO2 = -1.8255
		TEMPERATURE	P02 = 0.000000E+00
EH = 0.0000	PE = 100.000	15.00 DEG C	PCH4 = 0.000000E+00
PE CALC S = 1.000000E+02			C02 TOT = 5.848480E-03
PE CALC DOX = 1.000000E+02		IONIC STRENGTH	DENSITY = 1.0000
PE SATO DOX = 1.000000E+02		9.048088E-03	TDS = 476.2MG/L
TOT ALK = 5.177996E+00 MEQ/KG H2O			CARBONATE ALK = 5.177957E+00 MEQ/KG H2O
ELECT = -3.154725E-01 MEQ/KG H2O			
IN COMPUTING THE DISTRIBUTION OF SPECIES, PE = 100.000			EQUIVALENT EH = 5.718VOLTS



Table 7-12  
(Continued)

DISTRIBUTION OF SPECIES

I SPECIES		PPM	MOLALITY	LOG MOL	ACTIVITY	LOG ACT	ACT. COEFF.	LOG A COF
1 CA	2	7.41021E+01	1.84974E-03	-2.7329	1.26795E-03	-2.8969	6.85475E-01	-0.1640
2 MG	2	2.16812E+01	8.92217E-04	-3.0495	6.15144E-04	-3.2110	6.89456E-01	-0.1615
3 NA	1	6.47857E+00	2.81936E-04	-3.5498	2.56041E-04	-3.5917	9.08152E-01	-0.0418
4 K	1	9.28984E-01	2.37693E-05	-4.6240	2.15296E-05	-4.6670	9.05772E-01	-0.0430
64 H	1	6.17456E-05	6.12848E-08	-7.2126	5.62341E-08	-7.2500	9.17587E-01	-0.0374
5 CL	-1	1.99999E+01	5.64392E-04	-3.2484	5.11211E-04	-3.2914	9.05772E-01	-0.0430
6 SO4	-2	2.60278E+01	2.71078E-04	-3.5669	1.85025E-04	-3.7328	6.82553E-01	-0.1659
7 HCO3	-1	3.09380E+02	5.07277E-03	-2.2948	4.61648E-03	-2.3357	9.10050E-01	-0.0409
18 CO3	-2	2.67047E-01	4.45221E-06	-5.3514	3.05378E-06	-5.5152	6.85902E-01	-0.1637
86 H2CO3	0	4.21815E+01	6.80393E-04	-3.1672	6.81978E-04	-3.1662	1.00233E+00	0.0010
27 OH	-1	1.53471E-03	9.02808E-08	-7.0444	8.17483E-08	-7.0875	9.05489E-01	-0.0431
19 MGOM	1	3.30480E-04	8.00199E-09	-8.0968	7.30178E-09	-8.1366	9.12496E-01	-0.0398
23 MGS04 AQ	0	2.19443E+00	1.82389E-05	-4.7390	1.82769E-05	-4.7381	1.00209E+00	0.0009
22 MGHC03	1	2.93815E+00	3.44494E-05	-4.4628	3.12365E-05	-4.5053	9.06734E-01	-0.0425
21 MGC03 AQ	0	1.29321E-01	1.53439E-06	-5.8141	1.53759E-06	-5.8132	1.00209E+00	0.0009
29 CAOH	1	1.52032E-04	2.66441E-09	-8.5744	2.42835E-09	-8.6147	9.11401E-01	-0.0403
32 CAS04 AQ	0	5.94368E+00	4.36789E-05	-4.3597	4.37700E-05	-4.3588	1.00209E+00	0.0009
30 CAHC03	1	4.95180E+00	4.90039E-05	-4.3098	4.46622E-05	-4.3501	9.11401E-01	-0.0403
31 CAC03 AQ	0	4.53891E-01	4.53703E-06	-5.3432	4.54649E-06	-5.3423	1.00209E+00	0.0009
44 NAS04	-1	3.04804E-02	2.56149E-07	-6.5915	2.33109E-07	-6.6324	9.10050E-01	-0.0409
43 NAHC03	0	5.56853E-02	6.63308E-07	-6.1783	6.64691E-07	-6.1774	1.00209E+00	0.0009
42 NAC03	-1	7.83936E-04	9.44960E-09	-8.0246	8.59961E-09	-8.0655	9.10050E-01	-0.0409
94 NACL	0	1.90778E-04	3.26591E-09	-8.4860	3.27272E-09	-8.4851	1.00209E+00	0.0009
46 KS04	-1	3.46947E-03	2.56809E-08	-7.5904	2.33709E-08	-7.6313	9.10050E-01	-0.0409
95 KCL	0	2.12814E-05	2.85582E-10	-9.5443	2.86177E-10	-9.5434	1.00209E+00	0.0009
63 HS04	-1	8.21291E-05	8.46488E-10	-9.0724	7.68565E-10	-9.1143	9.07946E-01	-0.0419
96 H2S04	0	5.72385E-15	5.83883E-20	-19.2337	5.85100E-20	-19.2328	1.00209E+00	0.0009
93 HCL	0	2.78888E-13	7.65259E-18	-17.1162	7.66855E-18	-17.1153	1.00209E+00	0.0009

MOLE RATIOS FROM ANALYTICAL MOLALITY

CL/CA = 2.8987E-01  
CL/MG = 5.9631E-01  
CL/NA = 1.9953E+00  
CL/K = 2.3719E+01  
CL/AL = 5.6440E+26  
CL/FE = 5.6440E+26  
CL/SO4 = 1.6935E+00  
CL/HCO3 = 1.0900E-01  
CA/MG = 2.0571E+00  
NA/K = 1.1888E+01

MOLE RATIOS FROM COMPUTED MOLALITY

CL/CA = 3.0512E-01  
CL/MG = 6.3257E-01  
CL/NA = 2.0018E+00  
CL/K = 2.3745E+01  
CL/AL = 5.6439E+26  
CL/FE = 5.6439E+26  
CL/SO4 = 2.0820E+00  
CL/HCO3 = 1.1126E-01  
CA/MG = 2.0732E+00  
NA/K = 1.1861E+01

LOG ACTIVITY RATIOS

LOG CA/H2 = 11.6031  
LOG MG/H2 = 11.2890  
LOG NA/H1 = 3.6583  
LOG K/H1 = 2.5830  
LOG AL/H3 = -8.2500  
LOG FE/H2 = -15.5000  
LOG CA/MG = 0.3141  
LOG NA/K = 1.0753

PHASE	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT	DELGR
18 ANHYDRIT	2.3460E-07	3.5308E-05	-6.6297	-4.4521	6.6445E-03	-2.17754	-2.87114
22 ARAGONIT	3.8720E-09	7.2488E-09	-8.4121	-8.1397	5.3416E-01	-0.27233	-0.35907
151 ARTIN			-25.4842	-18.4127		-7.07154	-9.32401
20 BRUCITE	4.1109E-18	3.7015E-12	-17.3861	-11.4316	1.1106E-06	-5.95444	-7.85109
13 CALCITE	3.8720E-09	3.7749E-09	-8.4121	-8.4231	1.0257E+00	0.01104	0.01455
12 DOLOMITE	7.2736E-18	1.5519E-17	-17.1382	-16.8091	4.6869E-01	-0.32912	-0.43395
19 GYPSUM	2.3453E-07	2.5314E-05	-6.6298	-4.5966	9.2648E-03	-2.03316	-2.68078
65 HALITE	1.3089E-07	3.6195E+01	-6.8831	1.5586	3.6163E-09	-8.44174	-11.13066
118 HUNTITE			-34.5906	-29.8547		-4.73587	-6.24437
39 HYDMAG			-43.5648	-37.1709		-6.39397	-8.43062
11 MAGNESIT	1.8785E-09	8.2589E-09	-8.7262	-8.0831	2.2745E-01	-0.64311	-0.84795
67 MIRABI	1.2111E-11	2.5353E-02	-10.9168	-1.5960	4.7769E-10	-9.32086	-12.28979
59 NAHCOL	1.1820E-06	2.2771E-01	-5.9274	-0.6426	5.1909E-06	-5.28476	-6.96809
61 NATRON	1.9989E-13	1.9431E-02	-12.6992	-1.7115	1.0287E-11	-10.98772	-14.48759
150 NESQUE	1.8776E-09	8.0309E-06	-8.7264	-5.0952	2.3380E-04	-3.63115	-4.78777
66 THENAR	1.2130E-11	6.8478E-01	-10.9162	-0.1645	1.7713E-11	-10.75170	-14.17640
62 THRINAT	2.0016E-13	1.5714E+00	-12.6986	0.1963	1.2738E-13	-12.89489	-17.00225
60 TRONA	2.3656E-19	4.6011E-01	-18.6261	-0.3371	5.1414E-19	-18.28892	-24.11443

MKT/v)r/TEM/RSI  
[ndj-401-29J]  
12686.00-MD

TABLE 7-13

SAS Volatile Organic Sediment Data  
Sturgis Well Field RI/FS  
Sturgis, Michigan

SAMPLE ID:	SD01-01	SD01-91	SD02-01	SD03-01	SD04-01
SAMPLE DATE:	<u>9/11/87</u>	<u>9/11/87</u>	<u>9/14/87</u>	<u>9/14/87</u>	<u>9/25/87</u>
<u>Compounds</u>					
Methylene Chloride (ug/kg)	56.00 J/B	67.00 J/B	44.00 J/B	37.00 J/B	
2-Butanone (ug/kg)	16.00 R/U	16.00 R/U	13.00 R/U	12.00 R/U	21.R/U

MT/vlr/RSL  
[wptemp-402-90d]  
12686.70

Table 7-14

SAS Volatile Organic Surface Water Data  
Sturgis Well Field RI/FS  
Sturgis, Michigan

SAMPLE ID:	W01-01	W01-91	W02-01	W03-01	W04-01
SAMPLE DATE:	<u>9/11/87</u>	<u>9/11/87</u>	<u>9/14/87</u>	<u>9/14/87</u>	<u>9/25/87</u>
<u>Compounds</u>					
Trichloroethene (ug/L)					5.00
No Compounds Detected (ug/L)	0.00	0.00	0.00	0.00	

MT/vlr/RSL  
[wptemp-402-90e]  
12686.70

**Table 8-1. Potential Chemicals of Concern Detected in Sturgis Well Field Source Areas**

	Kirsch Co. Plant No. 1			Wade Electric			Telemark Business Forms	
	Soils	On-site Groundwater		Soils	On-site Groundwater		Soils	On-site Groundwater
VOCs								
Benzene								
Bromodichloromethane								
2-Butanone	X			X			X	
Chlorobenzene							X	
Chloroform				X			X	
1,1-Dichloroethane								
Total 1,2-Dichloroethene	X	X		X	X			X
1,1,2-Trichloroethane								
1,1,2,2-Tetrachloroethane								
Tetrachloroethene	X	X		X	X		X	X
1,1,1-Trichloroethane	X							
Trichloroethene	X	X		X	X		X	X
Vinyl Chloride				X				
Semi-volatile Compounds								
Potentially Carcinogenic PAHs	X			X				
Noncarcinogenic PAHs	X			X			X	
Bis(2-ethylhexyl)phthalate		X			X		X	
Butylbenzylphthalate	X						X	
Di-n-butylphthalate	X							
Di-n-octylphthalate		X		X				
PCBs/Pesticides								
Arochlor 1260	X							
Metals and Cyanide								
Barium	X	X		X	X		X	X
Chromium	X			X			X	X
Copper	X			X			X	
Lead	X			X			X	
Cyanide	X	X			X			

**Notes:**

Rationale for potential compounds of concern is presented in Table 10-2.

Compounds classified as potentially carcinogenic polycyclic aromatic

hydrocarbons include benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene

benzo(k)fluoranthene, dibenz(a,h)anthracene, chrysene, and indeno(1,2,3-c,d)pyrene.

TABLE 8-2

## PHYSICAL/CHEMICAL PROPERTIES OF TARGET COMPOUND LIST CHEMICALS

STURGIS WELL FIELD RI/FS  
STURGIS, MICHIGAN

	Density g/cc	Molecular Weight (g/mole)	Water Solubility (mg/l)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m <sup>3</sup> /mole)	Organic Carbon Partition Coefficient (ml/g)	Octanol Water Partition Coefficient (log10)
<u>Volatile</u>							
Chloromethane	0.92	50	6.50E+03	4.31E+03	4.40E-02	3.5E+01	0.95
Vinyl Chloride	1.37	63	2.67E+03	2.66E+03	8.19E-02	5.7E+01	1.38
Methylene Chloride	1.33	85(1)	2.00E+04(1)	3.60E+02(1)	--	--	--
Acetone	0.79	58	1.00E+06	2.70E+02	2.06E-05	2.2E+00	-0.24
1,1-Dichloroethene	1.22	97	2.25E+03	6.00E+02	3.40E-02	6.5E+01	1.84
1,1-Dichloroethane	1.18	99	5.50E+03	1.82E+02	4.31E-03	3.0E+01	1.79
1,2-Dichloroethene (Trans)	1.26	97	6.30E+03	3.24E+02	6.56E-03	5.9E+01	0.48
Chloroform	1.48	119	8.20E+03	1.51E+02	2.87E-03	3.1E+01	1.97
2-Butanone	0.81	72(1)	3.5E+05(1)	7.8E+01(1)	--	--	0.26(1)
1,1,1-Trichloroethane	1.34	133	1.50E+03	1.23E+02	1.44E-02	1.5E+02	2.5
Carbon Tetrachloride	1.59	154	7.57E+02	9.00E+01	2.41E-02	1.1E+02	2.64
Trichloroethene	1.46	131	1.10E+03	5.79E+01	9.10E-03	1.3E+02	2.38
1,1,2-Trichloroethane	1.44	133	4.50E+03	3.00E+01	1.17E-03	5.6E+01	2.47
Benzene	0.88	78	1.75E+03	9.52E+01	5.59E-03	8.3E+01	2.12
4-Methyl-2-Pentanone	0.80	100(1)	1.70E+04(1)	6.0E+00(1)	--	--	--
Tetrachloroethene	1.62	166	1.50E+02	1.78E+01	2.59E-02	3.6E+02	2.6
Toluene	0.87	92	5.35E+02	2.81E+01	6.37E-03	3.0E+02	2.73
Chlorobenzene	1.11	113	4.66E+02	1.17E+01	3.72E-03	3.3E+02	2.84
Ethylbenzene	0.87	106	1.52E+02	7.00E+00	6.43E-03	1.1E+03	3.15
Xylenes (total)	0.90	106	1.98E+02	1.00E+01	7.04E-03	2.4E+02	3.26
<u>Semivolatile</u>							
Phenol	1.07*	94	9.30E+04	3.41E-01	4.54E-07	1.4E+01	1.46
2-Chlorophenol	1.26	128(1)	2.60E+04(1)	--	--	--	2.50(1)
1,2-Dichlorobenzene	1.30	147	1.00E+02	1.00E+00	1.93E-03	1.7E+03	3.60
2-Methylphenol	1.03	108(1)	3.10E+04(1)	2.40E-01(1)	--	--	--
4-Methylphenol	1.02	108(1)	2.40E+04(1)	1.10E-01(1)	--	--	1.92(1)
Isophorone	0.92	138(1)	1.2E+04(1)	3.8E-01(1)	--	--	--
Benzoic Acid	1.27*	122(1)	2.9E+04(1)	--	--	--	1.87(1)
Naphthalene	0.96	128(1)	3.0E+01(1)	--	--	--	3.01(1)
2-Methylnaphthalene	1.01	142(2)	2.5E-02(2)	--	--	--	--
2-Chloronaphthalene	1.14*	162(2)	1.17E+01	--	--	--	--
Dimethylphthalate	--	194(1)	5.00E+03(1)	--	--	--	--

TABLE 8-2  
(Continued)

	Density g/cc	Molecular Weight (g/mole)	Water Solubility (mg/l)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m <sup>3</sup> /mole)	Organic Carbon Partition Coefficient (ml/g)	Octanol Water Partition Coefficient (log10)
Acenaphthylene	0.90*	152	3.93E+00	2.90E-02	1.48E-03	2.5E+03	3.7
Acenaphthene	1.02*	154	3.42E+00	1.55E-03	9.20E-05	4.6E+03	4.00
Dibenzofuran	1.09*	--	--	--	--	--	--
Fluorene	1.20*	116	1.69E+00	7.10E-04	6.42E-05	7.3E+03	4.20
Pentachlorophenol	--	266	1.40E+01	1.10E-04	2.75E-06	5.3E+04	5.01
Phenanthrene	0.98*	178	1.00E+00	6.80E-04	1.59E-04	1.4E+04	4.46
Anthracene	1.28*	178	4.50E-02	1.95E-04	1.02E-03	1.4E+04	4.45
Fluoranthene	1.25*	202	2.06E-01	5.00E-06	6.46E-06	3.8E+04	4.90
Pyrene	1.27*	202	1.32E-01	2.50E-06	5.04E-06	3.8E+04	4.88
Butylbenzylphthalate	--	312(1)	2.9E+00(1)	8.6E-06(1)	--	--	4.78(1)
Benzo(a)anthracene	--	228	5.70E-03	2.20E-08	1.16E-06	1.4E+06	5.60
Bis(2-Ethylhexyl)Phthalate	--	391	--	--	--	--	--
Chrysene	1.27	228	1.80E-03	6.30E-09	1.05E-06	2.0E+05	5.61
Di-n-octylphthalate	--	--	--	--	--	--	--
Benzo(b)fluoranthene	--	252	1.40E-02	5.00E-07	1.19E-05	5.5E+05	6.06
Benzo(k)fluoranthene	--	252	4.30E-03	5.10E-07	3.94E-05	5.5E+05	6.06
Benzo(a)pyrene	--	252	1.20E-03	5.60E-09	1.55E-06	5.5E+06	6.06
Indeno(1,2,3-cd)pyrene	--	276	5.30E-04	1.00E-10	6.86E-08	1.6E+06	6.50
Dibenz(a,h)anthracene	--	278	5.00E-04	1.00E-10	7.33E-08	3.3E+06	6.80
Benzo(g,h,i)perylene	--	276	7.00E-04	1.03E-10	5.34E-08	1.6E+06	6.51
<u>Pesticide</u>							
Arochlor 1260		328	3.10E-02	7.70E-05	1.07E-03	5.3E+05	6.04
<u>Heavy Metal</u>							
Chromium III and VI		52	--	0.00E+00	NA	--	--

A All values were obtained from the U.S. EPA Superfund Public Health Evaluation Manual (SPHEM), 1986 unless otherwise referenced.  
(--) indicates property not identified. Below are definitions of chemical properties.

Density of VOCs generally recorded at a temperature of 20° relative to water at 4°C. However, "\*" values were recorded at a different temperature (Refer to reference #6).

Water Solubility is the maximum concentration of a chemical that dissolves in pure water at a specific temperature and pH. Values are given for a neutral pH and a temperature range of 20 to 40° C. The rate at which a chemical is leached from a waste by infiltrating precipitation is a function of its solubility in water. The more soluble compounds are expected to be leached much more readily and rapidly than less soluble chemicals. The water solubilities presented in the literature indicate that the volatile organic chemicals are usually several orders of magnitude more water soluble than the base/neutral organic compounds (e.g., PAHs, PCBs).

TABLE 8-2  
(Continued)

Vapor pressure provides an indication of the rate at which a chemical in its pure state volatilizes. Values are given for a temperature range of 20 to 30° C. It is of primary significance where environmental interfaces such as surface soil/air and surface water/air occur. Volatilization is not as important when evaluating groundwater and subsurface soils. Chemicals with higher vapor pressures are expected to enter the atmosphere much more readily than chemicals with lower vapor pressures. Vapor pressures for monocyclic aromatic (toluene) and chlorinated aliphatics (TCE) are generally many times higher than vapor pressure for phthalate esters (bis(2-ethylhexyl)phthalate), polynuclear aromatic hydrocarbons (PAHs), and pesticides.

Henry's Law Constant is important in evaluating air exposure pathways. Values for Henry's Law Constant (H) were calculated using the following equation and the values previously recorded for solubility, vapor pressure, and molecular weight:

$$H(\text{atm-m}^3/\text{mole}) = \frac{\text{Vapor Pressure (atm)} \times \text{Mole Weight (g/mole)}}{\text{Water Solubility (g/m}^3\text{)}}$$

Organic Carbon Partition Coefficient (Koc) is a measure of the tendency for organics to be adsorbed by soil and sediment and is expressed as:

$$Koc = \frac{\text{mg chemical adsorbed/kg organic carbon}}{\text{mg chemical dissolved/liter of solution}}$$

The Koc is chemical specific and is largely independent of soil properties. In general, the Koc is inversely related to its environmental mobility. Refer to SPHEM for sources of the values.

The Octanol/Water Partition Coefficient is used to estimate bioconcentration factors in aquatic organisms. A linear relationship between the octanol/water partition coefficient and the uptake of chemicals by fatty tissues of animal and human receptors (the bioconcentration factor) has been determined. It is also useful in estimating the sorption and desorption of compounds by organic soils, where experimental values are not available.

- (1) Verschueren, K. Handbook of Environmental Data on Organic Chemicals. Van Nostrand Reinhold Co., New York, 1983.
- (2) Mackay, D. and Shire, W. Y. A critical review of Henry's Law constants for chemicals of environmental interest. J. Phys. Chem. Ref. Data. 10(4):1175-1199, 1981.
- (3) Weast, R.C. (ed) Handbook of Chemistry and Physics 54th Edition. CRC Press, Cleveland, 1973.

Table 8-3

**Summary of Important Solubility-Controlling Solids(a)  
Reported in the Literature  
Sturgis Well Field RI/FS  
Sturgis, Michigan**

<u>Element</u>	<u>Observed/Predicted(b)</u>	<u>Speculated(c)</u>
Al	Al(OH) <sub>3</sub> , KAl <sub>3</sub> (SO <sub>4</sub> ) <sub>2</sub> (OH) <sub>6</sub> , AlOHSO <sub>4</sub> , Kaolinite, Montmorillonite	
As		FeAsO <sub>4</sub> , AsS or As <sub>2</sub> S <sub>3</sub>
Ba	BaSO <sub>4</sub>	
Be		Be(OH) <sub>2</sub>
Cd	CdCO <sub>3</sub> , Cd <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub>	(Ca, Cd)CO <sub>3</sub>
Cr	Cr(OH) <sub>3</sub>	FeCr <sub>2</sub> O <sub>4</sub>
Cu	Cu(OH) <sub>2</sub>	Cu <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub> , Cu <sub>2</sub> (OH) <sub>2</sub> CO <sub>3</sub>
Fe	Fe(OH) <sub>3</sub> , Fe <sub>3</sub> (OH) <sub>8</sub> , FeCO <sub>3</sub>	
Hg	HgS	
Pb	Pb(OH) <sub>2</sub> , PbCO <sub>3</sub> , Pb <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> , Pb <sub>4</sub> O(PO <sub>4</sub> ) <sub>2</sub> , Pb <sub>5</sub> (PO <sub>4</sub> ) <sub>3</sub> OH	
Mn	MnCO <sub>3</sub> , Mn-oxides	
Mo	PbMoO <sub>4</sub>	FeMoO <sub>4</sub> , Fe <sub>2</sub> (MoO <sub>4</sub> ) <sub>3</sub>
Ni	NiS	NiFe <sub>2</sub> O <sub>4</sub>
Se		Fe <sub>2</sub> (SeO <sub>3</sub> ) <sub>3</sub>
S	CaSO <sub>4</sub> , Al <sub>4</sub> (OH) <sub>10</sub> SO <sub>4</sub> ·5H <sub>2</sub> O, KAl <sub>3</sub> (SO <sub>4</sub> ) <sub>2</sub> (OH) <sub>6</sub>	
V		Fe <sub>2</sub> (VO <sub>3</sub> ) <sub>2</sub> , VO(OH) <sub>2</sub> ·H <sub>2</sub> O
<u>Zn</u>	Zn(OH) <sub>2</sub> , ZnCO <sub>3</sub> , ZnSiO <sub>4</sub>	ZnFe <sub>2</sub> O <sub>4</sub>

(a) After, Battelle, Pacific Northwest Laboratories, 1984.

All solid phases are not expected in all environments; e.g., hydroxides and carbonate solids are expected only under near neutral to alkaline conditions and sulfides (e.g., HgS, NiS) are expected only under very reducing conditions; for details, see text.

(b) Solids whose presence has been established through physical observations of geologic materials or through similarities in ion activity products with the solubility products.

(c) The formation and presence of Fe-containing compounds are speculated primarily based on adsorption experiments or observed association of other elements with iron oxides.



TABLE 9-1

**Calibrated Model Parameters  
Sturgis Well Field RI/FS  
Sturgis, Michigan**

**1. Hydraulic Conductivity**

<u>Model Layer</u>	<u>Geologic Material</u>	<u>Horizontal</u>	<u>Vertical</u>
1	Sand & Gravel Aquifer	$4.3 \times 10^{-4}$ ft/sec	$4.3 \times 10^{-4}$ ft/sec
2	Till Confining Unit	$4.2 \times 10^{-6}$ ft/sec	$4.3 \times 10^{-6}$ ft/sec
	Sand & Gravel "Window"	$3.6 \times 10^{-4}$ ft/sec	$3.6 \times 10^{-4}$ ft/sec
3	Sand & Gravel Aquifer	$4.8 \times 10^{-4}$ ft/sec	$4.8 \times 10^{-4}$ ft/sec
4	Till Confining Unit	$4.9 \times 10^{-6}$ ft/sec	$4.9 \times 10^{-6}$ ft/sec
	Sand & Gravel "Window"	$4.6 \times 10^{-4}$ ft/sec	$4.6 \times 10^{-4}$ ft/sec
5	Sand & Gravel Aquifer	$4.7 \times 10^{-4}$ ft/sec	$4.7 \times 10^{-4}$ ft/sec
	"Channel Armor" Deposits	$4.3 \times 10^{-3}$ ft/sec	$4.3 \times 10^{-3}$ ft/sec

**2. Storage Factors**

<u>Model Layer</u>	<u>Storage Coefficient</u>
1	0.30
2	0.005
3	0.005
4	0.005
5	0.005

**3. River & Lake Properties**

Vertical Hydraulic Conductivity: River Beds	$1.1 \times 10^{-4}$ ft/s
Vertical Hydraulic Conductivity: Lake Beds	$6.6 \times 10^{-7}$ ft/s
Bed Thicknesses	1 ft

**4. Uniform Area Recharge Rate** 10.5 in/yr**Note:**

Confining units (model layers 2 & 4) are discontinuous in areas within the City. Therefore, it was necessary to describe certain of these areas with hydraulic properties of outwash materials.

**Table 10-1**  
**Organic and Inorganic Analytes**  
**Detected at the Sturgis Well Field Site<sup>a</sup>**

Environmental Medium	Analyte	Analyte Concentration		Number of Locations <sup>b</sup> Sampled for Analysis		
		Minimum	Maximum	Total	Positive Detection	
GROUNDWATER						
Currently used Municipal Wells Nos. 4, 5 and 6	<u>Volatile Organic</u>	<u>ug/L</u>	<u>ug/L</u>	3		
	Chloroform	1.0	1.0		1	
	Trichloroethene	1.0	1.0		1	
	<u>Semivolatile Organic</u>	<u>ug/L</u>	<u>ug/L</u>	3		
	Bis(2-ethylhexyl)phthalate	6.0	6.0		1	
	<u>Pesticide/PCB</u>			3		
	None Detected				0	
	<u>Metal/CNC</u>	<u>ug/L</u>	<u>ug/L</u>	3		
	Aluminum	44.0	51.0		2	
	Barium	30.2	51.7		3	
	Calcium	72,600	83,600		3	
	Iron	22.3	324		3	
	Lead	1.2	1.2		1	
	Magnesium	22,600	25,400		3	
	Manganese	34.0	94.5		3	
	Nickel	19.6	40.1		2	
	Potassium	1,060	1,150		2	
	Sodium	2,410	7,680		3	
	Zinc	44.0	219		2	
	All Wells; Monitoring Wells, Industrial Wells, and Municipal Wells	<u>Volatile Organic</u>	<u>ug/L</u>	<u>ug/L</u>	91	
		Acetone	3.0	5.0		5
		Benzene	0.2	2.0		3
		Bromodichloromethane	1.0	2.0		3
Chloroform		0.5	16		6	
Dibromochloromethane		1.0	1.0		2	
1,1-Dichloroethane		2.0	2.0		1	
1,2-Dichloroethane		1.0	1.0		2	
1,2-Dichloroethene (total)		0.5	17		10	
1,2-Dichloroethene (trans)		4.0	4.0		1	
2-Hexanone		0.6	0.6		1	
4-Methyl-2-pentanone		0.7	0.7		1	
1,1,2,2-Tetrachloroethane		0.3	0.3		1	
Tetrachloroethene		0.3	150		15	
1,1,1-Trichloroethane		0.3	9.0		10	
1,1,2-Trichloroethane		0.3	8.0		6	
Trichloroethene		0.2	17,000		49	
<u>Semivolatile Organic</u>		<u>ug/L</u>	<u>ug/L</u>	26		
Bis(2-ethylhexyl)phthalate		3.0	51		10	
Benzoic acid		4.0	4.0		1	
Di-n-octylphthalate		2.0	8.0		4	
<u>Pesticide/PCB</u>				26		
None Detected					0	

Table 10-1  
(Continued)

Environmental Medium	Analyte	Analyte Concentration		Number of Locations Sampled for Analysis	
		Minimum	Maximum	Total	Positive Detection
	<u>Metal/CNC</u>	<u>ug/L</u>	<u>ug/L</u>	26	
	Aluminum	20.5	106		16
	Antimony	197	197		1
	Arsenic	1.2	3.6		5
	Barium	24.0	176		26
	Beryllium	0.6	0.6		2
	Cadmium	4.8	5.7		3
	Calcium	37,000	190,000		26
	Chromium (total)	5.5	19.0		3
	Cobalt	6.9	6.9		1
	Copper	8.0	9.6		2
	Iron	18.0	1,970		23
	Lead	1.0	15.3		10
	Magnesium	2,540	117,000		26
	Manganese	0.61	462		20
	Mercury	0.2	0.3		2
	Nickel	6.6	40.1		4
	Potassium	500	25,000		26
	Selenium	1.1	5.3		14
	Sodium	1,520	543,000		26
	Thallium	1.1	1.1		1
	Zinc	31.0	17,800		24
	Cyanide (total)	10.4	247		4
<b>SUBSURFACE SOILS</b>					
Kirsch Co. Plant No. 1	<u>Volatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	12	
	Acetone	11.0	710		6
	Benzene	4.0	4.0		1
	Bromomethane	5.0	5.0		1
	2-Butanone	19.0	130		3
	1,2-Dichloroethene (total)	5.0	1,200		3
	Ethylbenzene	3.0	3.0		1
	Methylene chloride	3.0	94.0		6
	Tetrachloroethene	1.0	260,000		4
	Toluene	1.0	230		10
	1,1,1-Trichloroethane	3.0	10.0		2
	Trichloroethene	3.0	99,000		12
	Xylenes (total)	6.0	6.0		1
	<u>Semivolatile Organic<sup>d</sup></u>	<u>ug/kg</u>	<u>ug/kg</u>	8	
	Acenaphthylene	360	360		1
	Anthracene	52	760		4
	Benzo(a)anthracene	110	5,000		3
	Benzo(b)fluoranthene	47	5,100		4
	Benzo(k)fluoranthene	73	3,500		4
	Benzo(g,h,i)perylene	84	1,600		4
	Benzo(a)pyrene	82	5,100		4
	Butylbenzylphthalate	150	220		3
	Chrysene	120	4,000		4
	Dibenz(a,h)anthracene	81	1,100		2
	Dibenzofuran	130	180		2
	Di-n-butylphthalate	63	150		1
	Fluoranthene	68	5,200		5
	Fluorene	220	220		1
	Indeno(1,2,3-cd)pyrene	73	3,000		3
	2-Methylnaphthalene	420	420		1
	Naphthalene	170	290		2
	Pentachlorophenol	200	200		1
	Phenanthrene	160	3,600		4
	Pyrene	78	8,100		5
	Total Carcinogenic PAH	586	26,800		--

Table 10-1  
(Continued)

<u>Environmental Medium</u>	<u>Analyte</u>	<u>Analyte Concentration</u>		<u>Number of Locations<sup>b</sup> Sampled for Analysis</u>	
		<u>Minimum</u>	<u>Maximum</u>	<u>Total</u>	<u>Positive Detection</u>
	<u>Pesticide/PCB</u>	<u>ug/kg</u>	<u>ug/kg</u>	8	
	Aroclor-1260	290	290		1
	<u>Metal/CN</u>	<u>mg/kg</u>	<u>mg/kg</u>	8	
	Aluminum	1,990	15,600		8
	Antimony	17.6	17.6		1
	Arsenic	3.5	13.6		8
	Barium	11.1	249		8
	Beryllium	0.23	1.6		4
	Cadmium	1.2	5.2		7
	Calcium	1,120	101,000		8
	Chromium (total)	4.7	62.8		8
	Cobalt	3.2	13.2		6
	Copper	7.6	2,030		8
	Iron	7,390	108,000		8
	Lead	6.4	62.3		8
	Magnesium	1,180	17,600		8
	Manganese	160	2,340		8
	Mercury	0.16	0.35		3
	Nickel	7.2	69.4		8
	Potassium	284	1,280		4
	Silver	0.84	0.84		1
	Sodium	552	11,800		2
	Thallium	0.52	0.52		1
	Vanadium	7.0	40.5		8
	Zinc	26.5	2,010		8
	Cyanide (total)	1.5	188		4
Wade Electric Co.	<u>Volatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	6	
	Acetone	12.0	210		3
	2-Butanone	6.0	17.0		3
	Carbon tetrachloride	9.0	9.0		1
	Chlorobenzene	4.0	15.0		3
	Chloroform	3.0	42.0		1
	Chloromethane	6.0	8.0		2
	Methylene chloride	11.0	25.0		2
	Tetrachloroethene	7.0	630		1
	Toluene	1.0	250		4
	Trichloroethene	3.0	160		5
	Vinyl chloride	6.0	6.0		1
	<u>Semivolatile Organic<sup>d</sup></u>	<u>ug/kg</u>	<u>ug/kg</u>	6	
	Acenaphthylene	110	110		1
	Anthracene	240	240		1
	Benzo(a)anthracene	50.0	650		3
	Benzo(b)fluoranthene	89.0	1,400		3
	Benzo(g,h,i)perylene	56.0	89.0		1
	Benzo(a)pyrene	61.0	720		4
	Chrysene	49.0	1,000		3
	Dibenzofuran	170	170		1
	Di-n-octylphthalate	150	150		1
	Fluoranthene	88.0	1,200		3
	Indeno(1,2,3-cd)pyrene	49.0	75.0		1
	2-Methylnaphthalene	110	290		2
	Naphthalene	63.0	63.0		1
	Phenanthrene	52.0	1,600		3
	Pyrene	81.0	980		3
	Total Carcinogenic PAH	298	3,845		--

Table 10-1  
(Continued)

<u>Environmental Medium</u>	<u>Analyte</u>	<u>Analyte Concentration</u>		<u>Number of Locations<sup>b</sup> Sampled for Analysis</u>	
		<u>Minimum</u>	<u>Maximum</u>	<u>Total</u>	<u>Positive Detection</u>
	<u>Pesticide/PCB</u>			6	
	None Detected				0
	<u>Metal/CN</u>	<u>mg/kg</u>	<u>mg/kg</u>	6	
	Aluminum	1,920	9,160		6
	Antimony	11.0	70.0		6
	Arsenic	2.0	16.0		6
	Barium	6.5	71.0		6
	Beryllium	0.4	1.0		3
	Cadmium	0.9	2.9		3
	Calcium	1,650	90,200		6
	Chromium (total)	7.3	28.0		6
	Cobalt	2.9	7.0		5
	Copper	5.7	42.0		6
	Iron	5,430	36,200		6
	Lead	4.2	167		6
	Magnesium	1,630	11,700		6
	Manganese	168	1,100		6
	Mercury	0.1	0.13		2
	Nickel	7.3	21.0		6
	Potassium	339	722		6
	Silver	4.4	4.4		1
	Vanadium	6.0	32.0		6
	Zinc	15.0	167		6
Telemark Business Forms Co.	<u>Volatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	5	
	Acetone	5.0	36.0		1
	2-Butanone	5.0	5.0		1
	Chlorobenzene	2.0	19.0		3
	Chloroform	2.0	6.0		3
	Methylene chloride	3.0	9.0		1
	Tetrachloroethene	3.0	110		1
	Toluene	2.0	44.0		5
	Trichloroethene	2.0	2.0		1
	<u>Semivolatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	4	
	Benzoic acid	27.0	27.0		1
	Bis(2-ethylhexyl)phthalate	290	700		3
	Butylbenzylphthalate	16.0	500		2
	2-Methylnaphthalene	16.0	16.0		1
	Phenanthrene	14.0	14.0		1
	1,2,4-Trichlorobenzene	25.0	25.0		1
	<u>Pesticide/PCB</u>			4	
	None Detected				0
	<u>Metal/CN</u>	<u>mg/kg</u>	<u>mg/kg</u>	4	
	Aluminum	3,320	10,600		4
	Antimony	17.0	40.0		4
	Arsenic	3.3	12.0		4
	Barium	18.0	102		4
	Beryllium	0.4	0.6		3
	Cadmium	1.9	2.9		3
	Calcium	662	77,800		4
	Chromium (total)	3.4	16.0		4
	Cobalt	3.5	6.2		4

Table 10-1  
(Continued)

<u>Environmental Medium</u>	<u>Analyte</u>	<u>Analyte Concentration</u>		<u>Number of Locations<sup>b</sup> Sampled for Analysis</u>	
		<u>Minimum</u>	<u>Maximum</u>	<u>Total</u>	<u>Positive Detection</u>
	Copper	7.5	19.0		4
	Iron	7,570	25,900		4
	Lead	4.7	23.0		4
	Magnesium	752	21,800		4
	Manganese	201	794		4
	Nickel	4.7	20		3
	Potassium	268	576		4
	Vanadium	13.0	23.0		4
	Zinc	2.9	83.0		4
<b>SURFACE SOIL</b>					
Kirsch Co. Plant No. 1	<u>Volatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	8	
	Toluene	3.0	5.0		5
	1,1,1-Trichloroethane	2.0	4.0		4
	Trichloroethene	2.0	2.0		3
	<u>Semi Volatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	8	
	Acenaphthene	51.0	1,500		5
	Acenaphthylene	35.0	44.0		2
	Anthracene	92.0	2,800		6
	Benzo(a)anthracene	42.0	4,500		8
	Benzo(b)fluoranthene	76.0	5,900		8
	Benzo(k)fluoranthene	76.0	5,900		8
	Benzo(g,h,i)perylene	210	1,200		6
	Benzo(a)pyrene	37.0	3,600		8
	Bis(2-ethylhexyl)phthalate	49.0	130		5
	Butylbenzylphthalate	280	450		2
	Chrysene	50.0	4,100		8
	Dibenz(a,h)anthracene	130	380		5
	Dibenzofuran	55.0	870		5
	Di-n-butylphthalate	39.0	190		7
	Fluoranthene	87.0	9,100		8
	Flourene	49.0	1,300		5
	Ideno (1,2,3-cd)pyrene	230	1,300		6
	2-Methylnaphthalene	66.0	250		5
	Naphthalene	92.0	1,400		5
	Phenanthrene	660	8,700		6
	Pyrene	77.0	8,400		8
	Total Carcinogenic PAH	641	25,700		--
	<u>Pesticide/PCB</u>	<u>ug/kg</u>	<u>ug/kg</u>	8	
	Aroclor-1260	420	1,500		3
	Beta-BHC	84.0	84.0		1
	<u>Metal/CN</u>	<u>mg/kg</u>	<u>mg/kg</u>	8	
	Aluminum	4,850	7,940		8
	Arsenic	3.0	6.9		8
	Barium	66.5	181		8
	Beryllium	0.72	0.93		3
	Cadmium	0.91	0.91		1
	Calcium	4,030	44,400		8
	Chromium (total)	7.6	16.6		8
	Cobalt	3.5	5.9		8
	Copper	6.8	92.1		8
	Iron	7,880	15,800		8
	Lead	9.1	63.3		8
	Magnesium	1,780	5,720		8
	Manganese	335	727		8
	Nickel	5.1	12.5		8

Table 10-1  
(Continued)

<u>Environmental Medium</u>	<u>Analyte</u>	<u>Analyte Concentration</u>		<u>Number of Locations<sup>b</sup> Sampled for Analysis</u>	
		<u>Minimum</u>	<u>Maximum</u>	<u>Total</u>	<u>Positive Detection</u>
	Potassium	342	886		8
	Selenium	0.55	0.63		3
	Vanadium	12.4	21.7		8
	Zinc	42.5	136		8
	Cyanide (total)	1.5	1.5		1
Wade Electric Co.	<u>Volatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	4	
	Acetone	18.0	18.0		2
	Chloroform	10.0	10.0		1
	Tetrachloroethene	2.0	6.0		2
	Toluene	1.0	4.0		3
	1,1,1-Trichloroethane	1.0	2.0		4
	<u>Semi Volatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	4	
	Acenaphthylene	44.0	44.0		1
	Anthracene	42.0	70.0		2
	Benzo(a)anthracene	58.0	380		4
	Benzo(b)flouranthene	89.0	630		4
	Benzo(k)flouranthene	48.0	630		4
	Benzo(g,h,i)perylene	130	300		2
	Benzo(a)pyrene	63.0	360		4
	Bis(2-ethylhexyl)phthalate	94.0	400		4
	Butylbenzylphthalate	42.0	72.0		2
	Chrysene	69.0	410		4
	Dibenzofuran	110	110		1
	Di-n-butylphthalate	76.0	76.0		1
	Flouranthene	89.0	570		4
	Indeno(1,2,3-cd)pyrene	45.0	160		3
	2-Methylnaphthalene	400	400		1
	Naphthalene	260	260		1
	Phenanthrene	44.0	410		4
	Pyrene	83.0	660		4
	Total Carcinogenic PAH	480	2,680		--
	<u>Pesticide/PCBs</u>	<u>ug/kg</u>	<u>ug/kg</u>	4	
	Dieldrin	26.0	26.0		1
	4,4-DDT	18.0	18.0		1
	<u>Metal/CN</u>	<u>mg/kg</u>	<u>mg/kg</u>	4	
	Aluminum	2,970	8,390		4
	Arsenic	3.1	6.1		4
	Barium	39.1	132		4
	Beryllium	0.67	1.1		2
	Cadmium	2.8	2.8		1
	Calcium	8,410	67,800		4
	Chromium (total)	7.5	47.0		4
	Cobalt	3.4	6.2		4
	Copper	19.2	41.5		4
	Iron	8,780	26,900		4
	Lead	36.2	95.7		4
	Magnesium	1,980	9,300		4
	Manganese	345	3,800		4
	Nickel	7.3	11.5		4
	Potassium	345	644		4
	Vanadium	9.5	15.8		4
	Zinc	77.0	120		4
Telemark Business Forms Co.	<u>Volatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	2	
	Tetrachloroethene	2.0	14.0		2
	Toluene	5.0	6.0		2

Table 10-1  
(Continued)

<u>Environmental Medium</u>	<u>Analyte</u>	<u>Analyte Concentration</u>		<u>Number of Locations<sup>b</sup> Sampled for Analysis</u>	
		<u>Minimum</u>	<u>Maximum</u>	<u>Total</u>	<u>Positive Detection</u>
	<u>Semi Volatile Organic</u>	<u>ug/kg</u>	<u>ug/kg</u>	<u>2</u>	
	bis(2-ethylhexyl)phthalate	120	120		1
	<u>Pesticide/PCB</u>	<u>ug/kg</u>	<u>ug/kg</u>	<u>2</u>	
	None Detected				0
	<u>Metal/CN</u>	<u>mg/kg</u>	<u>mg/kg</u>	<u>2</u>	
	Aluminum	3,790	6,220		2
	Arsenic	4.3	4.7		2
	Barium	24.5	39.2		2
	Beryllium	0.65	0.65		1
	Cadmium	0.85	0.85		1
	Calcium	12,700	35,600		2
	Chromium (total)	7.5	22.4		2
	Cobalt	3.8	6.0		2
	Copper	11.4	15.0		2
	Iron	9,850	15,300		2
	Lead	15.7	24.3		2
	Magnesium	7,070	10,900		2
	Manganese	300	372		2
	Nickel	8.5	15.1		2
	Potassium	335	497		2
	Vanadium	11.1	21.9		2
	Zinc	43.1	57.1		2

<sup>a</sup> Data summarized are only from CLP analyses. Refer to Appendices E and F contained in the RI Report to determine total parameters analyzed and associated detection limits. Only analytes which were identified above detection limits are summarized.

<sup>b</sup> A location (well or soil boring) was considered to be positive for the presence of a given analyte if the analyte was detected during any sampling round and, in the case of soil borings, at any depth.

<sup>c</sup> Data summary does not include SAS analysis for sodium, potassium, calcium and magnesium.

<sup>d</sup> Compounds classified as potentially carcinogenic polycyclic aromatic hydrocarbons (PAH) include benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, chrysene and indeno(1,2,3-c,d)pyrene.

BJC/vlr/KJD/KJD  
[vlr-401-40]  
60251.17-MD



**Table 10-2**  
**Evaluation**  
**Chemicals of Potential Concern**  
**Sturgis Well Field Site**

<u>Chemical</u>	<u>Chemical of Potential Concern</u>	<u>Location Chemical Detected</u>	<u>Rationale for Selection or Exclusion</u>
<b>GROUNDWATER</b>			
Acetone	No	Total Wells	Present in some, but not all field and laboratory blanks. Considered artifact of sampling or laboratory analysis.
Benzene	Yes	Total Wells	Present at three locations. Possible site contaminant, however, may also be sampling or laboratory artifact based on infrequent detection at low concentrations.
Bromodichloromethane	Yes	Total Wells	Possible site contaminant, however, may also be due to sample contamination or residual chlorinated water in the municipal well samples.
Chloroform	Yes	Total Wells, Municipal Wells	Probably site contaminant at some locations, however, may also be due to sample contamination or residual chlorinated water in the municipal well samples.
Dibromochloromethane	Yes	Total Wells	Possible site contaminant, however, may also be due to sample contamination.
1,1-Dichloroethane	Yes	Total Wells	Possible degradation product of trichloroethane.
1,2-Dichloroethane	Yes	Total Wells	Possible degradation product of trichloroethane.
1,2-Dichloroethene (total)	Yes	Total Wells	Possible degradation product of TCE and PCE.
2-Hexanone	No	Total Wells	Present at 1 of 91 sampling locations at very low concentrations. May be laboratory contaminant.
4-Methyl-2-pentanone	No	Total Wells	Present at 1 of 91 sampling locations at very low concentrations. May be laboratory contaminant.
1,1,2,2-Tetrachloroethane	Yes	Total Wells	Possible site contaminant, although detected at only 1 of 91 sample locations at very low concentration. Chosen based on its similarity to other chlorinated ethanes.
Tetrachloroethene	Yes	Total Wells	Site contaminant present in groundwater and soils.
1,1,1-Trichloroethane	Yes	Total Wells	Site contaminant present in groundwater and soils.

Table 10-2  
(Continued)

Chemical	Chemical of Potential Concern	Location Chemical Detected	Rationale for Selection or Exclusion
1,1,2-Trichloroethane	Yes	Total Wells	Possible site contaminant.
Trichloroethene	Yes	Total Wells, Municipal Wells	Site contaminant present in groundwater and soils.
bis(2-Ethylhexyl)phthalate	Yes	Total Wells, Municipal Wells	Possible site contaminant, however, also common laboratory and sampling contaminant and may therefore be artifact.
Benzoic Acid	No	Total Wells	Detected in 1 of 26 samples at a low concentration.
Di-n-octylphthalate	Yes	Total Wells	Possible site contaminant, however, also common laboratory and sampling contaminant and may therefore be artifact.
Barium	Yes/No	Total Wells, Municipal Wells	May be elevated at some locations, although range of natural concentrations appears variable. Not elevated at municipal wells.
Chromium	Yes	Total Wells	Appears elevated at two locations.
Iron	No	Total Wells, Municipal Wells	Elevated at one location.
Manganese	No	Total Wells, Municipal Wells	Elevated at one location.
Other metals detected but not listed	No	Total Wells, Municipal Wells	Appear to be within range of naturally occurring concentrations.
Cyanide (total)	Yes	Total Wells	Elevated at several locations.
<b>SUBSURFACE SOILS</b>			
Acetone	No	Kirsch, Wade, Telemark	Present in some but not all laboratory blanks. Considered laboratory contaminant.
Benzene	No	Kirsch	Identified at only one location at a low concentration.
Bromomethane	No	Kirsch	Identified at only one location at a low concentration.
2-Butanone	Yes	Kirsch, Wade, Telemark	Possible contaminant, although its presence in some samples may be artifact of laboratory analysis.
Carbon Tetrachloride	No	Wade	Present in one sample from one location at 20 ft, but not at more surficial depths.
Chlorobenzene	Yes	Wade, Telemark	Consistent identification at several locations.
Chloroform	Yes	Wade, Telemark	Consistent identification at several locations.
Chloromethane	No	Wade	Present in samples from two locations at 20 and 30 ft, but not at more surficial locations.

Table 10-2  
(Continued)

Chemical	Chemical of Potential Concern	Location Chemical Detected	Rationale for Selection or Exclusion
1,2-Dichloroethene (total)	Yes	Kirsch	Possible degradation product of PCE and TCE.
Ethylbenzene	No	Kirsch	Present in one sample from one location at a low concentration.
Methylene Chloride	No	Kirsch, Wade, Telemark	Present in some but not all laboratory blanks. Considered laboratory contaminant.
Tetrachloroethene	Yes	Kirsch, Wade, Telemark	Site contaminant present in soil and groundwater.
Toluene	No	Kirsch, Wade, Telemark	Considered result of contaminated sample containers. Toluene contamination confirmed in groundwater blanks by field GC and CLP analyses.
1,1,1-Trichloroethane	Yes	Kirsch	Site contaminant present in soil and groundwater.
Trichloroethene	Yes	Kirsch, Wade, Telemark	Site contaminant present in soil and groundwater.
Vinyl chloride	Yes	Wade	Possible degradation product of PCE and TCE.
Xylenes (total)	No	Kirsch	Present in one sample from one location at a low concentration.
Potentially carcinogenic polycyclic aromatic hydrocarbons	Yes	Kirsch, Wade	Group B2 carcinogen concentrations summed and evaluated as Benzo(a)pyrene.
Noncarcinogenic polycyclic aromatic hydrocarbons	Yes	Kirsch, Wade, Telemark	Individual compounds assessed when reference dose available.
Benzoic acid	No	Telemark	Present at only one location.
Bis(2-ethylhexyl)phthalate	Yes	Telemark	Compound may also be an artifact of sampling or laboratory analysis.
Butylbenzylphthalate	Yes	Kirsch, Telemark	Compound may also be an artifact of sampling or laboratory analysis.
Di-n-butylphthalate	Yes	Kirsch	Compound may also be an artifact of sampling or laboratory analysis.
Di-n-octylphthalate	Yes	Wade	Compound may also be an artifact of sampling or laboratory analysis.
Pentachlorophenol	No	Kirsch	Present in only one sample from one location.
1,2,4-Trichlorobenzene	No	Telemark	Present in only one sample from one location.
Aroclor - 1260	Yes	Kirsch	Also present in surface soils.

Table 10-2  
(Continued)

Chemical	Chemical of Potential Concern	Location Chemical Detected	Rationale for Selection or Exclusion
Zinc	Yes	Kirsch	Appear elevated over apparent naturally occurring concentrations.
Chromium	Yes	Kirsch	Appear elevated over apparent naturally occurring concentrations.
Copper	Yes	Kirsch	Appear elevated over apparent naturally occurring concentrations.
Lead	Yes	Wade	May be elevated at only one location.
Cyanide	Yes	Kirsch	Present in soils and groundwater.
Other metals detected but not listed	No	Kirsch, Wade, Telemark	Appear within apparent, naturally occurring concentrations.
<b>SURFACE SOILS</b>			
Acetone	No	Wade	Present in some but not all laboratory blanks. Considered laboratory contamination.
Chloroform	No	Wade	Present in laboratory blanks. Considered laboratory contamination.
1,1,1-Trichloroethane	Yes	Kirsch, Wade	Site contaminant, present in soils and groundwater.
Trichloroethene	Yes	Kirsch	Site contaminant, present in soils and groundwater.
Tetrachloroethene	Yes	Wade, Telemark	Site contaminant, present in soils and groundwater.
Toluene	No	Kirsch, Wade, Telemark	Considered result of contaminated sample containers. Toluene contamination confirmed in groundwater blanks by field GC and CLP analyses.
Potentially carcinogenic polycyclic aromatic hydrocarbons	Yes	Kirsch, Wade	Group B2 carcinogen concentrations summed and evaluated as benzo(a)pyrene.
Noncarcinogenic polycyclic aromatic hydrocarbons	Yes	Kirsch, Wade	Individual compounds assessed when reference dose available.
Bis(2-ethylhexyl)phthalate	Yes	Kirsch, Wade, Telemark	Compound may also be an artifact of sampling or laboratory analysis.
Butylbenzylphthalate	Yes	Kirsch, Wade	Compound may also be an artifact of sampling or laboratory analysis.

Table 10-2  
(Continued)

Chemical	Chemical of Potential Concern	Location Chemical Detected	Rationale for Selection or Exclusion
Di-n-butylphthalate	Yes	Kirsch, Wade	Compound may also be an artifact of sampling or laboratory analysis.
Aroclor-1260	Yes	Kirsch	Present in three sample locations.
Pesticides; beta-BHC, dieldrin, 4,4-DDT	No	Kirsch, Wade	Identified at one location.
Copper	Yes	Kirsch	Elevated in subsurface soil and several surface locations.
Cyanide	Yes	Kirsch	Elevated in subsurface soil and one surface soil location.
Other metals detected but not listed	No	Kirsch, Wade, Telemark	Appear within apparent, naturally occurring concentrations.

Notes:

This table summarizes the selection or exclusion of identified sample constituents as chemicals of potential concern for further consideration in the risk assessment. Chemicals addressed are those which were positively identified through CLP analysis of samples. The location where the analytes were detected is indicated. Total wells refers to an evaluation of the combined data from all groundwater sampling points (i.e., monitoring, municipal, and industrial wells). Municipal wells refers to those currently used for water supply by the City, Wells PW4, PW5 and PW6. Carcinogenic polycyclic aromatic hydrocarbons are listed in legend to Table 1.

BJC/vlr/KJD/KJD  
[vlr-401-40a]  
60251.17-MD

Table 10-3  
Potential Exposure Pathways  
Sturgis Well Field Site

-----CURRENT LAND USE CONDITIONS-----

Environmental Medium	Exposure Point	Exposed Population	Routes of Contaminant Intake	Pathway Currently Complete?	Exposure Potential	Risk Quantified?
Groundwater	Municipal water supply	Residents of Sturgis	Ingestion, dermal absorption while bathing	Yes, low levels of TCE detected in Round 4 samples from PW4, currently used for municipal water.	Very low, alternate use of water from municipal wells is expected to reduce TCE concentrations to very low levels at tap	Yes
	Private well water	Residents with private potable wells	Ingestion, dermal absorption while bathing	No, identified existing private wells not located within zone of contamination	None	No
Surface Soil	Open source areas at Kirsch Plant No. 1, Wade Electric and Telemark Co.	Children playing	Incidental ingestion, dermal absorption	Unknown, but possible. Access to areas is not restricted	Low, areas are generally vegetated and contaminant concentrations are low	Yes
Subsurface Soil	None, subsurface location prohibits direct contact	None	None	No	None	No
Ambient Air	Outdoor air	Residents of Sturgis	Inhalation	Unknown, but possible air sampling not performed. Photoionization detector readings show non-detectable levels (<1 ppm).	Low, volatilization of organics from soils not anticipated to be appreciable as a result of dilution and dispersion in ambient air	Yes, volatile chemical emission and air dispersion modeled.
Surface Water/Sediment	None, contaminated surface waters not present on-site	None	None	No	None	No

Table 10-3  
(Continued)

-----POTENTIAL FUTURE LAND USE CONDITIONS-----

Environmental Medium	Exposure Point	Exposed Population	Routes of Contaminant Intake	Exposure Potential	Risk Quantified?
Groundwater	Municipal water supply	Residents of Sturgis	Ingestion, dermal absorption while bathing	Possible, additional municipal wells could become contaminated in future.	This pathway is considered by evaluating water use by private well owners, below.
	Private well water	Residents with current or future private potable wells	Ingestion, dermal absorption while bathing	Unlikely but possible, if current policy requiring Health Department permitting is waived and a well is installed within the zone of contamination. Also, migration of contamination to existing wells is possible.	Yes, assume future private well may be installed at any point in the aquifer. Assume contaminant levels remain as under current conditions.
Surface and Subsurface soils	Yard at future residence	Future resident	Incidental ingestion, dermal absorption	Possible, assume property is developed with residence and contaminated soils, surface and subsurface, are located at ground surface.	Yes, assume lifetime exposure to resident.
Ambient Air	Outdoor air	Residents of Sturgis	Inhalation	Possible. If contaminated soils are brought to surface by Site development, a short-term increase in volatilization may occur compared to current conditions.	No, this pathway is addressed under current site conditions.
Surface Water/ Sediment	Low, contaminated surface waters not present on-site. In absence of pumping, groundwater could discharge to local surface water bodies.	Individuals recreating in water bodies	Incidental ingestion, dermal absorption	Very low, City requires pumping of groundwater preventing migration to surface water.	No

Table 10 - 4

## ESTIMATION OF VOLATILE CHEMICAL CONCENTRATIONS IN AMBIENT AIR

Sturgis Well Field Site  
Sturgis, Michigan

COMPOUND	----- Chemical Emission (Ei) Calculation Variables -----									Estimated Downwind Concentration 100 m
	MW (g/mole)	VP (mm Hg)	Csi (g/cm3)	ADV (cm3/mole)	Di @ 19 C (cm2/sec)	Max. Soil Conc. (ug/kg)	Mf uM/kg soil	Mi (mole/mole)	Ei (g/sec)	(g/m3)
KIRSCH Co. PLANT No. 1										
Total-1,2-Dichloroethene	97	2.08e+02	1.00e-09	75.96	9.11e-02	1.20e+00	1.24e-02	5.30e-03	1.58e-08	1.33e-11
1,1,1-Trichloroethane	133	1.23e+02	1.17e-08	97.44	7.96e-02	1.00e-02	7.52e-05	3.22e-05	9.79e-10	8.29e-13
Trichloroethene	131	5.79e+01	1.20e-06	93.48	8.12e-02	9.90e+01	7.56e-01	3.23e-01	1.02e-03	8.67e-07
Tetrachloroethene	166	1.78e+01	2.90e-07	111	7.40e-02	2.60e+02	1.57e+00	6.70e-01	4.70e-04	3.98e-07
WADE Co.										
Trichloroethene	131	5.79e+01	3.50e-08	93.48	8.12e-02	1.60e+02	1.22e+00	2.09e-01	6.95e-06	5.88e-09
Tetrachloroethene	166	1.78e+01	9.78e-08	111	7.40e-02	6.30e+02	3.80e+00	6.51e-01	5.50e-05	4.66e-08
TELEMARK BUSINESS FORMS Co.										
Trichloroethene	131	5.79e+01	1.57e-08	93.48	8.12e-02	2.00e-03	1.53e-05	1.58e-02	1.16e-08	9.83e-12
Tetrachloroethene	166	1.78e+01	1.07e-08	111	7.40e-02	1.10e-01	6.63e-04	6.86e-01	3.13e-07	2.65e-10

This table summarizes the mathematical relationships used to model chemical emission rates from soils and the dispersion of chemical concentrations in air at a distance of 100 meters from the source. The relationships were obtained from the "Superfund Exposure Assessment Manual" (SEAM), 1988. The following defines the column headings:  
 MW, molecular weight; VP, vapor pressure; Csi, saturation vapor concentration; ADV, atomic diffusion volume; Di, diffusion coefficient; Max. Soil Conc., maximum soil concentration; Mf, mmoles contaminant per kg soil; Mi, mole fraction (i.e. fraction of total moles for each chemical); Ei, estimated emission rate. The following describes the equations and Site specific variables:

Csi = The maximum soil gas concentration from all samples collected from each of the three areas, and converted to g/cm3.

Max. Soil Conc. = The maximum soil concentration from all samples collected from each of the three areas.

$$Di = \frac{0.001 * T^{1.75} * ((1/MW) + (1/MWa))^{(1/2)}}{[(ADV^{(1/3)} + (ADVa^{(1/3)}))^{1/2}]}$$

where:

(MWa) molecular wt. of air = 28.8 g/mole  
 (ADVa) atomic diffusion volume of air = 20.1 cm3/mole  
 (T) temperature in degrees K = 293.15  
 ^ = exponent



Table 10 - 4  
(continued)

ESTIMATION OF VOLATILE CHEMICAL CONCENTRATIONS IN AMBIENT AIR

Sturgis Well Field Site  
Sturgis, Michigan

$$E_i = \frac{D_i * C_{si} * A * Pt^{(4/3)} * M_i}{D_{sc}}$$

where:

(A) area = 8.44e+07 cm<sup>2</sup>, Kirsch Co  
          = 3.02e+07 cm<sup>2</sup>, Wade Electric  
          = 1.49e+06 cm<sup>2</sup>, Telemark  
(D<sub>sc</sub>) depth of soil cover for all properties = 762 cm  
(Pt) soil porosity = 0.4  
Pt<sup>(4/3)</sup> = 2.95e-01  
^ = exponent

$$C(x) = \frac{E_i}{(\pi * O_y * O_z * u)} * 0.30$$

where:

C(x) = concentration at distance x  
pi = 3.14  
O<sub>y</sub> = lateral dispersion coefficient, stability class D = 8 m  
O<sub>z</sub> = vertical dispersion coefficient, stability class D = 4.7 m  
u = average wind speed (assume 3 m/s)  
0.3 = assume wind blows 30 % of the time towards receptor

Default equation variables were obtained from SEAM. Refer to SEAM for further information.

JAH/jah/MMK  
Version 2/26/91  
[sturgis2.2020]v-1-22.w20

Table 10-5

**Summary of Contaminant Intake Methods and Assumptions  
Sturgis Well Field Site**

Exposure Route,  
Equation

Variable

Value Used

Rationale

**Groundwater-Ingestion for municipal  
or private water use**

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

CW = Chemical Concentration in Water (mg/liter)

IR = Ingestion Rate (liters/day)

2

- 90th percentile of adult average

EF = Exposure Frequency (day/year)

365

- Daily exposure

ED = Exposure Duration (years)

70

- MDNR convention

BW = Body Weight (kg)

70

- Adult average

AT = Averaging Time (days)

25,550

- Exposure duration, i.e. Lifetime.

**Groundwater-Dermal  
absorption while bathing for  
municipal or private water use**

Absorbed Dose  
(mg/kg-day) =

$$\frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

CW = Chemical Concentration in Water (mg/liter)

SA = Skin Surface Area Available for Contact (cm<sup>2</sup>)

18,100

- 50th percentile adult (male/female average)

PC = Chemical-Specific Dermal Permeability Constant (cm/hr)

8.4x10<sup>-4</sup>

- Value for water, suggested in absence of chemical-specific value. Chemical-Specific values for benzene (0.41) and chromium (0.0021) were obtained from SEAM.

ET = Exposure Time (hours/day)

0.2

- 90th percentile suggested value

EF = Exposure Frequency (days/year)

365

- Daily activity

ED = Exposure Duration (years)

70

- MDNR convention

CF = Volumetric Conversion Factor (liter/cm<sup>3</sup>)

0.001

BW = Body Weight (kg)

70

- Adult average

AT = Averaging Time (days)

25,550

- Exposure duration, i.e. Lifetime.

Table 10-5  
(Continued)

Exposure Route, Equation	Variable	Value Used	Rationale
<b>Ambient Air - Inhalation of Volatile Chemicals</b>			
Intake (mg/kg-day) =	CA = Chemical Concentration in Air (mg/m <sup>3</sup> )		
$\frac{CA \times IR \times EF \times ED}{BW \times AT}$	IR = Inhalation Rate (m <sup>3</sup> /day)	30	- Upper bound value.
	EF = Exposure Frequency (days/year)	365	- Daily activity.
	ED = Exposure Duration (years)	70	- MDNR convention.
	BW = Body Weight (kg)	70	- Adult average.
	AT = Averaging Time (days)	25,550	- Exposure duration, i.e. lifetime.
<b>Surface Soil - Dermal absorption for child playing on company property</b>			
Absorbed Dose (mg/kg-day) =	CS = Chemical Concentration in Soil (mg/kg)		
$\frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$	CF = Conversion Factor (kg/mg)	10 <sup>-6</sup>	
	SA = Skin Surface Area Available for Contact (cm <sup>2</sup> /event)	2,490	- SA for older children, outdoor value Michigan Risk Assessment Guidelines.
	AF = Soil to Skin Adherence Factor (mg/cm <sup>2</sup> )	0.512	- AF for older children, outdoor value Michigan Risk Assessment Guidelines.
	ABS = Absorption Factor (unitless)	0.10/0.01	- Assume 10% for volatile organic chemicals, 1% for other organics and inorganics. Michigan Risk Assessment Guidelines.
	EF = Exposure Frequency (events/year)	24	- One event per week during 6 months. Subjective judgement.
	ED = Exposure Duration (years)	10	- Occurs from ages 5 to 15. Subjective judgement
	BW = Body Weight (kg)	30	- 50th Percentile body weight, male child 9 to 10 years old
	AT = Averaging Time (days)	3650 for non-carcinogens 25,550 for carcinogens	- Exposure duration for noncarcinogenic effects. Lifetime for cancer effects.

Table 10-5  
(Continued)

Exposure Route, Equation	Variable	Value Used	Rationale
<b>Surface Soil - Incidental ingestion for child playing on company property</b>			
Absorbed Dose (mg/kg-day) =	CS = Chemical Concentration in Soil (mg/kg)		
$\frac{CS \times IR \times CF \times ABS \times FI \times EF \times ED}{BW \times AT}$	IR = Ingestion Rate (mg soil/day)	175	- Maximum intake, derived from Michigan Risk Assessment Guidelines.
	CF = Conversion Factor (kg/mg)	10 <sup>-6</sup>	
	FI = Fraction Ingested from Contaminated Source (unitless)	1.0	- Assume entire area contaminated. Subjective judgement.
	ABS = Absorption Factor (unitless)	1.0/0.5	- Assume 100% for volatile organic chemicals, 50% for other organics and inorganics. Michigan Risk Assessment Guidelines.
	EF = Exposure Frequency (days/years)	24	- One event per week during 6 months. Subjective judgement.
	ED = Exposure Duration (years)	10	- Occurs from ages 5 to 15. Subjective judgement.
	BW = Body Weight (kg)	30	- 50th Percentile body weight, male child 9 to 10 years old.
	AT = Averaging Time (days)	3650 for non-carcinogens 25,550 for carcinogens	- Exposure duration for noncarcinogenic effects. Lifetime for cancer effects.
<b>Subsurface Soil - Lifetime dermal absorption for future resident</b>			
Absorbed Dose (mg/kg-day) =	CS = Chemical Concentration in Soil (mg/kg)		
$\frac{CS \times CF \times SCR \times ABS \times EF \times ED}{BW \times AT}$	CF = Conversion Factor (kg/mg)	10 <sup>-6</sup>	
	SCR = Soil Contact Rate (mg/d)	900	- Normalized value based on 6 month, daily exposure. Michigan Risk Assessment Guidelines.
	ABS = Absorption Factor (unitless)	0.10/0.01	- Assume 10% for volatile organic chemicals, 1% for other organics and inorganics. Michigan Risk Assessment Guidelines.

Table 10-5  
(Continued)

Page 4 of 5

Exposure Route,  
Equation

Variable

Value Used

Rationale

EF = Exposure Frequency (events/year)

365

- Daily for 6 mo. of year. SCR is a normalized value based on 6 month exposure, thus, 365 is used.

ED = Exposure Duration (years)

70

- MDNR Convention.

BW = Body Weight (kg)

70

- Adult Average.

AT = Averaging Time (days)

25,550

- Exposure duration, i.e., lifetime.

Surface Soil - Lifetime incidental  
ingestion for future resident

Absorbed Dose  
(mg/kg-day) =

$$\frac{CS \times IR \times CF \times ABS \times FI \times EF \times ED}{BW \times AT}$$

CS = Chemical Concentration in Soil (mg/kg)

IR = Ingestion Rate (mg soil/day)

90

- Normalized value based on 6 month, daily exposure. Michigan Risk Assessment Guidelines.

CF = Conversion Factor (kg/mg)

10<sup>-6</sup>

FI = Fraction Ingested from Contaminated Source (unitless)

1.0

- Assume entire area contaminated. Subjective judgement.

ABS = Absorption Factor (unitless)

1.0/0.5

- Assume 100% for volatile organic chemicals, 50% for other organics and inorganics. Michigan Risk Assessment Guidelines.

EF = Exposure Frequency (days/years)

365

- Daily for 6 months of year. The IR is a normalized value based on 6 month exposure, thus, 365 is used.

ED = Exposure Duration (years)

70

- MDNR convention.

BW = Body Weight (kg)

70

- Adult average.

AT = Averaging Time (days)

25,550

- Exposure duration, i.e., lifetime.

Notes: Exposure equations and suggested exposure factors from the Draft State of Michigan Risk Assessment Guidelines (1990), the Human Health Evaluation Manual (EPA, 1989) or, the Exposure Factors Handbook (EPA, 1989).

The soil adherence factor used in estimating dermal exposure for children trespassers was the value for soil adherence specified for older children in the Michigan guidelines. The soil incidental ingestion rate was derived by averaging the value for the 5 to 11 year age group (250 mg/day) with the value for individuals 11 yr and older (100 mg/day).

Table 10-6

**Toxicity Values Used for Quantitative Risk Assessment  
Sturgis Well Field Site**

Compound	Oral Toxicity Values for <sup>a</sup> Comparison with Administered Dose Estimates		U.S. EPAb Carcinogen Classification (Group)	Estimate of CompoundC Absorption Efficiency from Oral Administration		Adjusted Oral Toxicity Valuesd for Comparison with Absorbed Dose Estimates	
	Chronic Reference Dose	Slope Factor				Chronic Reference Dose	Slope Factor
	(mg/kg-day)	(kg-day/mg)		(%)	(Basis)	(mg/kg-day)	(kg-day/mg)
VOLATILE ORGANIC							
Benzene	--	0.029	A	100	d	--	0.029
Bromodichloromethane	0.02	0.13	B2	100	d	0.02	0.13
2-Butanone	0.05	--	D	100	d	0.05	--
Chlorobenzene	0.02	--	--	100	b	0.02	--
Chloroform	0.01	0.0061	B2	100	a	0.01	0.0061
Dibromochloromethane	0.02	0.084	C	100	d	0.02	0.084
1,1-Dichloroethane	0.1	--	C	100	c	0.1	--
1,2-Dichloroethane	--	0.091	B2	100	b	--	0.091
1,2-Dichloroethene (cis)	0.01	--	--	100	c	0.01	--
1,1,2,2-Tetrachloroethane	--	0.2	C	100	d	--	0.2
Tetrachloroethene	0.01	0.051	B2	100	d	0.01	0.051
1,1,1-Trichloroethane	0.09	--	D	100	a	0.09	--
1,1,2-Trichloroethane	0.004	0.057	C	100	c	0.004	0.057
Trichloroethene	--	0.011	B2	SF is based on absorbed dose		--	0.011
Vinyl Chloride	--	2.3	A	100	b	--	2.3
SEMIVOLATILE ORGANIC							
Acenaphthene	0.06	--	--	50	d	0.03	--
Anthracene	0.3	--	D	50	d	0.15	--
Bis(2-ethylhexyl)phthalate	0.02	0.014	B2	50	d	0.01	0.028
Butylbenzylphthalate	0.2	--	C	50	d	0.1	--
Di-n-butylphthalate	0.1	--	--	50	d	0.05	--
Carcinogenic Polyaromatic Hydrocarbons (benzo(a)pyrene)	--	11.8	B2	50	d	--	23.6
Flouranthene	0.04	--	--	50	d	0.02	--
Flourene	0.04	--	D	50	d	0.02	--
Naphthalene	0.004	--	D	50	d	0.002	--
Pyrene	0.03	--	D	50	d	0.015	--
Polychlorinated biphenyls	--	7.7	B2	50	d	--	15.4
METAL/CN							
Barium	0.05	--	D	5	d	0.0025	--
Chromium (VI)	0.005	--	D	5	b	0.00025	--
Copper	--	--	D	--	--	--	--
Cyanide	0.02	--	D	70	b	0.014	--
Zinc	0.2	--	D	5	d	0.01	--

Table 10-6  
(Continued)

a Toxicity values were obtained from the U.S. EPA's Integrated Risk information System or U.S. EPA's Health Effects Assessment Summary Tables (Third Quarter FY-1990).

b U.S. EPA's Weight-of-Evidence Classification System for Carcinogenicity is described as follows:

<u>Group</u>	<u>Description</u>
A	Human carcinogen
B1 or B2	Probable human carcinogen B1 indicates that limited human data are available. B2 indicates sufficient evidence in animals and inadequate or no evidence in humans.
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity for humans

c Information pertaining to the oral absorption efficiency of a compound was obtained from U.S. EPA Health Effects Assessment documents for individual compounds. The basis for the absorption estimate is as follows:

- (a) Studies on specified compound in humans
- (b) Studies on specified compound in laboratory animals
- (c) Studies on chemically related compound in humans or laboratory animals.

When no information on the absorption of a compound or related compound was available, it was assumed that the absorption of volatile organic compounds is 100%, the absorption of semivolatile compounds is 50% and the absorption of inorganic compounds is 5%. These default assumptions are designated (d).

d Adjustment of toxicity values based on administered doses to values based on absorbed doses is described by the following relationships:

Reference Dose (administered) x Oral Absorption Efficiency = Reference Dose (absorbed)

Slope Factor (administered) ÷ Oral Absorption Efficiency = Slope Factor (absorbed)



Table 10-7

**Chemical Hazard Index Estimates for  
Current Land Use Exposure Scenarios  
Sturgis Well Field Site**

Chemicals Potentially Causing Noncancer Health Hazards	Contaminant Dose . Estimate (mg/kg-d)		RFD or Adjusted RFD (mg/kg-d)	Critical Effect	Uncertainty Factor	Hazard Quotient		Total Exposure Pathway Hazard Index
	Incidental Ingestion	Dermal Absorption				Incidental Ingestion	Dermal Absorption	
----- Residents Utilizing Water from the Municipal Supply -----								
Chloroform	2.9e-05	4.3e-08	1.0e-02	Liver lesions	1000	2.9e-03	4.1e-06	
Bis(2-ethylhexyl)phthalate	1.7e-04	2.6e-07	2.0e-02	Liver weight	1000	<u>8.6e-03</u>	<u>2.5e-05</u>	
					Total	1.1e-02	2.9e-05	1e-02
----- Children Playing on Company Property - Contact with Surface Soils -----								
KIRSCH CO. PLANT NO. 1								
1,1,1-Trichloroethane	1.5e-09	1.1e-09	9.0e-02	Liver tox.	1000	1.7e-08	1.2e-08	
Acenaphthene	2.8e-07	4.2e-08	3.0e-02	Liver tox.	3000	9.5e-06	1.4e-06	
Anthracene	5.3e-07	7.8e-08	1.5e-01	No effects	3000	3.5e-06	5.2e-07	
Fluorene	2.5e-07	3.6e-08	2.0e-02	Blood changes	3000	1.2e-05	1.8e-06	
Fluoranthene	1.7e-06	2.5e-07	2.0e-02	Neuro tox.	3000	8.6e-05	1.3e-05	
Naphthalene	2.7e-07	3.9e-08	2.0e-03	Eye tox.	10000	1.3e-04	2.0e-05	
Pyrene	1.6e-06	2.3e-07	1.5e-02	Kidney tox.	3000	1.1e-04	1.6e-05	
Bis(2-ethylhexyl)phthalate	2.5e-08	3.6e-09	1.0e-02	Liver weight	1000	2.5e-06	3.6e-07	
Butylbenzylphthalate	8.6e-08	1.3e-08	1.0e-01	Body weight	1000	8.6e-07	1.3e-07	
Di-n-butylphthalate	3.6e-08	5.3e-09	5.0e-02	Mortality	1000	7.2e-07	1.1e-07	
Cyanide	2.9e-07	4.2e-08	1.4e-02	Weight loss	500	<u>2.0e-05</u>	<u>3.0e-06</u>	
					Total	3.8e-04	5.6e-05	4e-04
WADE ELECTRIC CO.								
1,1,1-Trichloroethane	7.7e-10	5.6e-10	9.0e-02	Liver tox.	1000	8.5e-09	6.2e-09	
Tetrachloroethene	2.3e-09	1.7e-09	1.0e-02	Liver tox.	1000	2.3e-07	1.7e-07	
Anthracene	1.3e-08	2.0e-09	1.5e-01	No effects	3000	8.9e-08	1.3e-08	
Fluoranthene	1.1e-07	1.6e-08	2.0e-02	Neuro tox.	3000	5.4e-06	8.0e-07	
Naphthalene	4.9e-08	7.3e-09	2.0e-03	Eye tox.	10000	2.5e-05	3.6e-06	
Pyrene	1.2e-07	1.8e-08	1.5e-02	Kidney tox.	3000	8.4e-06	1.2e-06	
Bis(2-ethylhexyl)phthalate	7.6e-08	1.1e-08	1.0e-02	Liver weight	1000	7.6e-06	1.1e-06	
Butylbenzylphthalate	1.4e-08	2.0e-09	1.0e-01	Body weight	1000	1.4e-07	2.0e-08	
Di-n-butylphthalate	1.4e-08	2.1e-09	5.0e-02	Mortality	1000	<u>2.3e-07</u>	<u>4.3e-08</u>	
					Total	4.7e-05	6.9e-06	5e-05

Table 10-7  
(Continued)

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Chemicals Potentially Causing Noncancer Health Hazards	Contaminant Dose Estimate (mg/kg-d)		RFD or Adjusted RFD (mg/kg-d)	Critical Effect	Uncertainty Factor	Hazard Quotient		Total Exposure Pathway Hazard Index
	Incidental Ingestion	Dermal Absorption				Incidental Ingestion	Dermal Absorption	
TELEMARK BUSINESS FORMS								
Tetrachloroethene	5.3e-09	3.9e-09	1.0e-02	Liver tox.	1000	5.3e-07	3.9e-07	
Bis(2-ethylhexyl)phthalate	2.3e-08	3.4e-09	1.0e-02	Liver weight	1000	<u>2.3e-06</u>	<u>3.4e-07</u>	
					Total	2.8e-06	7.3e-07	4e-06

Notes:

Hazard indices were estimated for each exposure pathway by summing the chemical-specific hazard quotients for the ingestion and dermal absorption of contaminants. Contaminant dose estimates were derived using maximum contaminant concentrations (Table 10-1) and the equations shown in Table 10-5. Hazard quotients are calculated by dividing the dose estimate by the RFD. Also shown are the critical toxic effects for each RFD and the safety factor applied to account for the uncertainty in the derivation of the RFD.

**Table 10-8**  
**Cancer Risk Estimates for**  
**Current Land Use Exposure Scenarios**  
**Sturgis Well Field Site**

Potential Carcinogens	Contaminant Dose Estimate (mg/kg-d)		SF or Adjusted SF (kg-d/mg)	Type of Cancer	Weight of Evidence	Chemical-Specific Risk		Total Exposure Pathway Risk
	Incidental Ingestion	Dermal Absorption				Incidental Ingestion	Dermal Absorption	
----- Residents Using Water from the Municipal Supply -----								
Chloroform	2.9e-05	4.3e-08	6.1e-03	Kidney	B2	1.7e-07	2.5e-10	
Trichloroethene	2.9e-05	4.3e-08	1.1e-02	Liver	B2	3.1e-07	4.6e-10	
Bis(2-ethylhexyl) phthalate	1.7e-04	2.6e-07	1.4e-02	Liver	B2	2.4e-06	7.0e-10	
					Total	2.9e-06	8.0e-09	3e-06
----- Children Playing on Company Property - Contact with Surface Soils -----								
KIRSCH CO. PLANT NO. 1								
Trichloroethene	1.1e-10	8.0e-11	1.1e-02	Liver	B2	1.2e-12	8.8e-13	
Bis(2-ethylhexyl)phthalate	3.6e-09	5.2e-10	2.8e-02	Liver	B2	1.0e-10	1.5e-11	
Total carcinogenic PAHs	7.1e-07	1.0e-07	2.4e+01	Stomach	B2	1.7e-05	2.4e-06	
PCB	4.1e-08	6.0e-09	1.5e+01	Liver	B2	6.3e-07	9.2e-08	
					Total	1.8e-05	2.5e-06	2e-05
WADE ELECTRIC CO.								
Tetrachloroethene	3.3e-10	2.4e-10	5.1e-02	Liver	B2	1.7e-11	1.2e-11	
Bis(2-ethylhexyl)phthalate	1.1e-08	1.6e-09	2.8e-02	Liver	B2	3.1e-10	4.5e-11	
Total Carcinogenic PAHs	7.4e-08	1.1e-08	2.4e+01	Stomach	B2	1.7e-06	2.5e-07	
					Total	1.7e-06	2.5e-07	2e-06
TELEMARK BUSINESS FORMS								
Tetrachloroethene	7.7e-10	5.6e-10	5.1e-02	Liver	B2	3.9e-11	2.9e-11	
Bis(2-ethylhexyl)phthalate	3.3e-09	4.8e-10	2.8e-02	Liver	B2	9.2e-11	1.3e-11	
					Total	1.3e-10	4.2e-11	2e-10

**Notes:**

Cancer risks were estimated for each exposure pathway by summing the chemical-specific risks for ingestion and dermal absorption of contaminants. Contaminant dose estimates were derived using maximum contaminant concentrations (Table 10-1) and the equations shown in Table 10-5. Cancer risk is calculated by multiplying the contaminant dose by the slope factor. Also shown is the type of cancer and the EPA weight-of-evidence classification for each chemical. This classification is defined in the legend to Table 10-6.

Table 10-9

**Cancer and Noncancer Health Risks Associated With Contaminated Air  
Current Land Use Exposure Scenario  
Sturgis Well Field Site**

<u>Chemical of Potential Concern</u>	<u>Exposure Point Concentration (mg/m<sup>3</sup>)</u>	<u>Contaminant Dose Estimate (mg/kg-d)</u>	<u>Inhalation Reference Dose (mg/kg-d)</u>	<u>Inhalation Slope Factor (kg-d/mg)</u>	<u>Hazard Quotient</u>	<u>Total Exposure Pathway Hazard Index</u>	<u>Cancer Risk</u>	<u>Total Exposure Pathway Cancer Risk</u>
<b>Kirsch Co. Plant No. 1</b>								
Tetrachloroethane	4.0e-04	1.7e-04	--	3.3e-03	--		5.7e-07	
1,1,1-Trichloroethane	8.3e-10	3.6e-10	3.0e-01	--	1.2e-09		--	
Trichloroethene	8.7e-04	3.7e-04	--	1.7e-02	--	1.2e-9	6.3e-06	6.9e-06
<b>Wade Electric Co.</b>								
Tetrachloroethene	4.7e-05	2.0e-05	--	3.3e-03	--		6.6e-08	
Trichloroethene	5.9e-06	2.5e-06	--	1.7e-02	--	--	4.3e-08	1.1e-7
<b>Telemark Business Forms</b>								
Tetrachloroethene	2.6e-07	1.1e-07	--	3.3e-03	--		3.7e-10	
Trichloroethene	9.8e-09	4.2e-09	--	1.7e-02	--	--	7.1e-11	4.4e-10

Legend

-- = No toxicity value (i.e., reference dose or slope factor) available.

Table 10-10

**Chemical Hazard Index Estimates for Potential  
Future Land Use Exposure Scenarios  
Sturgis Well Field Site**

Chemicals Potentially Causing Noncancer Health Hazards	Contaminant Dose Estimate (mq/kg-d)		RFD or Adjusted RFD (mq/kg-d)	Critical Effect	Uncertainty Factor	Hazard Quotient		Total Exposure Pathway Hazard Index
	Incidental Ingestion	Dermal Absorption				Incidental Ingestion	Dermal Absorption	
----- Residents Utilizing Contaminated Groundwater from a Private Well -----								
Bromodichloromethane	5.7e-05	8.7e-08	2.0e-02	Kidney tox.	1000	2.9e-03	4.1e-06	
Chloroform	4.6e-04	7.0e-07	1.0e-02	Liver lesions	1000	4.6e-02	6.6e-05	
Dibromochloromethane	2.9e-05	4.3e-09	2.0e-02	Liver tox.	1000	1.4e-03	2.1e-06	
1,1-Dichloroethane	5.7e-05	8.7e-08	1.0e-01	Kidney tox.	1000	5.7e-04	8.3e-07	
1,2-Dichloroethene (total)	4.9e-04	7.4e-07	1.0e-02	Blood enzyme	1000	2.4e-02	3.5e-05	
Tetrachloroethene	4.3e-03	6.5e-06	1.0e-02	Liver tox.	1000	4.3e-01	6.2e-04	
1,1,1-Trichloroethane	2.6e-04	3.9e-07	9.0e-02	Liver Tox.	1000	2.9e-03	4.1e-06	
1,1,2-Trichloroethane	2.3e-04	3.5e-07	4.0e-03	Blood Chemistry	1000	5.7e-02	8.3e-05	
Bis(2-ethylhexyl)phthalate	1.5e-03	2.2e-06	2.0e-02	Liver weight	1000	7.3e-02	2.1e-04	
Barium	5.0e-03	7.6e-06	5.0e-02	Fetus tox.	100	1.0e-01	2.9e-03	
Chromium	5.4e-04	8.3e-07	5.0e-03	Not defined	500	5.4e-04	4.1e-05	
Cyanide	7.1e-03	1.1e-05	2.0e-02	Weight Loss	500	3.5e-01	7.3e-04	
TOTAL						1.1e+00	4.7e-03	1e+00

----- Lifetime Exposure of Future Residents to Contaminated Soils -----

**KIRSCH CO. PLANT NO. 1**

Total 1,2-Dichloroethene	1.5e-06	1.5e-06	1.0e-02	Blood enzyme	1000	1.5e-04	1.5e-04	
2-Butanone	1.7e-07	1.7e-07	5.0e-02	Fetus tox.	1000	3.3e-06	3.3e-06	
1,1,1-Trichloroethane	1.3e-08	1.3e-08	9.0e-02	Liver tox.	1000	1.4e-07	1.4e-07	
Tetrachloroethene	3.3e-04	3.3e-04	1.0e-02	Liver tox.	1000	3.3e-02	3.3e-02	
Naphthalene	9.2e-07	1.8e-07	2.0e-03	Eye tox.	10000	4.6e-04	9.2e-05	
Fluorene	8.3e-07	1.7e-07	2.0e-02	Blood changes	3000	4.2e-05	8.3e-06	
Anthracene	1.8e-06	3.6e-07	1.5e-01	No effects	3000	1.2e-05	2.4e-06	
Di-n-butylphthalate	1.2e-07	2.4e-08	5.0e-02	Mortality	1000	2.4e-06	4.9e-07	
Fluoranthene	5.8e-06	1.2e-06	2.0e-02	Neuro tox.	3000	3.0e-04	5.8e-05	
Pyrene	5.4e-06	1.0e-06	1.4e-03	Kidney tox.	3000	3.6e-04	7.2e-05	
Butylbenzylphthalate	2.9e-07	5.7e-08	1.0e-01	Body weight	1000	2.9e-06	5.7e-07	
Acenaphthene	9.7e-07	1.9e-07	3.0e-02	Liver tox.	3000	3.2e-05	6.5e-06	
Bis(2-ethylhexyl)phthalate	8.4e-08	1.7e-08	1.0e-02	Liver weight	1000	8.4e-06	1.7e-06	
Chromium	4.0e-05	8.1e-06	2.5e-04	Not defined	500	1.6e-01	3.3e-02	
Cyanide	1.2e-04	2.4e-05	1.4e-02	Weight loss	500	8.6e-03	1.7e-03	
Zinc	1.3e-03	2.6e-04	1.0e-02	Anemia		1.3e-01	2.6e-02	
TOTAL						3.4e-01	9.4e-02	4e-01

Table 10-10  
(Continued)

Chemicals Potentially Causing Noncancer Health Hazards	Contaminant Dose Estimate (mg/kg-d)		RFD or Adjusted RFD (mg/kg-d)	Critical Effect	Uncertainty Factor	Hazard Quotient		Total Exposure Pathway Hazard Index
	Incidental Ingestion	Dermal Absorption				Incidental Ingestion	Dermal Absorption	
WADE ELECTRIC CO.								
Chloroform	5.4e-08	5.4e-08	1.0e-02	Liver lesions	1000	5.4e-06	5.4e-06	
2-Butanone	2.2e-08	2.2e-08	5.0e-02	Fetus tox.	1000	4.4e-07	4.4e-07	
Tetrachloroethene	8.1e-07	8.1e-07	1.0e-02	Liver tox.	1000	8.1e-05	8.1e-05	
Chlorobenzene	1.9e-08	1.9e-08	2.0e-02	Liver tox.	1000	9.6e-07	9.6e-07	
Naphthalene	1.7e-07	3.3e-08	2.0e-03	Eye tox.	10000	8.2e-05	1.7e-05	
Anthracene	1.5e-07	3.1e-08	1.5e-01	No effects	3000	1.0e-06	2.1e-07	
Fluoranthene	7.7e-07	1.5e-07	2.0e-02	Neuro tox.	3000	3.9e-05	7.7e-06	
Pyrene	6.3e-07	1.3e-07	1.4e-02	Kidney tox.	3000	4.2e-05	8.4e-06	
Bis(2ethylhexyl)phthalate	2.6e-07	5.2e-08	1.0e-02	Liver weight	1000	2.6e-05	5.2e-06	
Butylbenzylphthalate	4.7e-08	9.4e-09	1.0e-01	Body weight	1000	4.7e-07	9.4e-08	
Di-n-butylphthataate	4.9e-08	9.9e-09	5.0e-02	Mortality	1000	9.9e-07	1.9e-07	
					TOTAL	2.8e-04	1.3e-04	4e-04
TELEMARK BUSINESS FORMS								
Chloroform	7.7e-09	7.7e-09	1.0e-02	Liver lesions	1000	7.7e-07	7.7e-07	
2-Butanone	6.4e-09	6.4e-09	5.0e-02	Fetus tox.	1000	1.3e-07	1.3e-07	
Tetrachloroethene	1.4e-07	1.4e-07	1.0e-02	Liver tox.	1000	1.4e-05	1.4e-05	
Chlorobenzene	2.4e-08	2.4e-08	2.0e-02	Liver tox.	1000	1.2e-06	1.2e-06	
Butylbenzylphthalate	3.2e-07	6.4e-08	1.0e-01	Body weight	1000	3.2e-06	6.4e-07	
Bis(2-ethylhexyl)phthalate	4.5e-07	9.0e-08	1.0e-02	Liver weight	1000	4.5e-05	9.0e-06	
					TOTAL	6.4e-05	2.6e-05	9e-05
Notes:								

Notes:

Hazard indices were estimated for each exposure pathway by summing the chemical-specific hazard quotients for the ingestion and dermal absorption of contaminants. Contaminant dose estimates were derived using maximum contaminant concentrations (Table 10-1) and the equations shown in Table 10-5. Hazard quotients are calculated by dividing the dose estimate by the RFD. Also shown are the critical toxic effects for each RFD and the safety factor applied to account for the uncertainty in the derivation of the RFD.

BJC/vlr/MWK/KJD  
[vlr-401-40f]  
12686.00-MD

Table 10-11

**Cancer Risk Estimates for Potential  
Future Land Use Exposure Scenarios  
Sturgis Well Field Site**

Potential Carcinogens	Contaminant Dose Estimate (mg/kg-d)		SF or Adjusted SF (kg-d/mg)	Type of Cancer	Weight of Evidence	Chemical-Specific Risk		Total Exposure Pathway Risk
	Incidental Ingestion	Dermal Absorption				Incidental Ingestion	Dermal Absorption	
----- Residents Utilizing Contaminated Groundwater from a Private Well -----								
Benzene	5.7e-05	8.7e-08	2.9e-02	Leukemia	A	1.7e-06	1.2e-06	
Bromodichloromethane	5.7e-05	8.7e-08	1.3e-01	Liver	B2	7.4e-06	1.1e-08	
Chloroform	4.6e-04	7.0e-07	6.1e-03	Kidney	B2	2.8e-06	4.0e-09	
Dibromochloromethane	2.9e-05	4.3e-08	8.4e-02	Liver	C	2.4e-06	3.6e-09	
1,2-Dichloroethane	2.9e-05	4.3e-08	9.1e-02	Circulatory System	B2	2.6e-06	3.8e-09	
Tetrachloroethene	4.3e-03	6.5e-06	5.1e-02	Liver	B2	2.2e-04	3.2e-07	
1,1,2,2-Tetrachloroethane	8.6e-06	1.3e-08	2.0e-01	Liver	C	1.7e-06	2.5e-09	
1,1,2-Trichloroethane	2.3e-04	3.5e-07	5.7e-02	Liver	C	1.3e-05	1.9e-08	
Trichloroethene	4.9e-01	7.4e-04	1.1e-02	Liver	B2	5.3e-03	7.7e-06	
Bis(2-ethylhexyl)Phthalate	1.5e-03	2.2e-06	1.4e-02	Liver	B2	2.0e-05	5.9e-08	
					Total	5.6e-03	9.4e-06	6e-03
----- Lifetime Exposure of Future Residents to Contaminated Soils -----								
KIRSCH CO. PLANT NO. 1								
Trichloroethene	1.3e-04	1.3e-04	1.1e-02	Liver	B2	1.4e-06	1.4e-06	
Tetrachloroethene	3.3e-04	3.3e-04	5.1e-02	Liver	B2	1.7e-05	1.7e-05	
Bis(2-ethylhexyl)phtalate	8.4e-08	1.7e-08	2.8e-02	Liver	B2	2.4e-09	4.7e-10	
Total carcinogenic PAHs	1.7e-05	3.4e-06	2.4e+01	Stomach	B2	4.1e-04	8.3e-05	
PCBs	9.7e-07	1.9e-07	1.5e+01	Liver	B2	1.5e-05	3.0e-06	
					Total	4.4e-04	1.0e-04	5e-04
WADE ELECTRIC CO.								
Vinyl Chloride	7.7e-09	7.7e-09	2.3e+00	Lung	A	1.8e-08	1.8e-08	
Chloroform	5.4e-08	5.4e-08	6.1e-03	Kidney	B2	3.3e-10	3.3e-10	
Trichloroethene	2.1e-07	2.1e-07	1.1e-02	Liver	B2	2.3e-09	2.3e-09	
Tetrachloroethene	8.1e-07	8.1e-07	5.1e-02	Liver	B2	4.1e-08	4.1e-08	
Bis(2-ethylhexyl)phtalate	2.6e-07	5.2e-08	2.8e-02	Liver	B2	7.3e-09	1.5e-09	
Total carcinogenic PAHs	2.5e-06	4.9e-07	2.4e+01	Stomach	B2	5.9e-05	1.2e-05	
					Total	5.9e-05	1.2e-05	7e-05

Table 10-11  
(Continued)

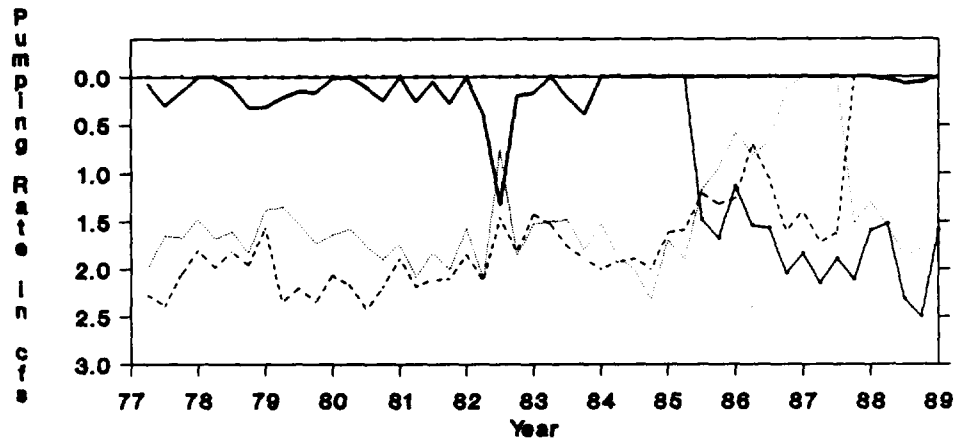
<u>Potential Carcinogens</u>	<u>Contaminant Dose Estimate (mg/kg-d)</u>		<u>SF or Adjusted SF (kg-d/mg)</u>	<u>Type of Cancer</u>	<u>Weight of Evidence</u>	<u>Chemical-Specific Risk</u>		<u>Total Exposure Pathway Risk</u>
	<u>Incidental Ingestion</u>	<u>Dermal Absorption</u>				<u>Incidental Ingestion</u>	<u>Dermal Absorption</u>	
TELEMARK BUSINESS FORMS								
Chloroform	7.7e-09	7.7e-09	6.1e-03	Kidney	B2	4.7e-11	4.7e-11	
Trichloroethene	2.6e-09	2.6e-09	1.1e-02	Liver	B2	2.8e-11	2.8e-11	
Tetrachloroethene	1.4e-07	1.4e-07	5.1e-02	Liver	B2	7.2e-09	7.2e-09	
Bis(2-ethylhexyl)phthalate	4.5e-07	9.0e-08	2.8e-02	Liver	B2	1.3e-08	2.5e-09	
					Total	2.0e-08	9.8e-09	.3e-08

Notes:

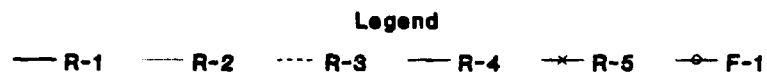
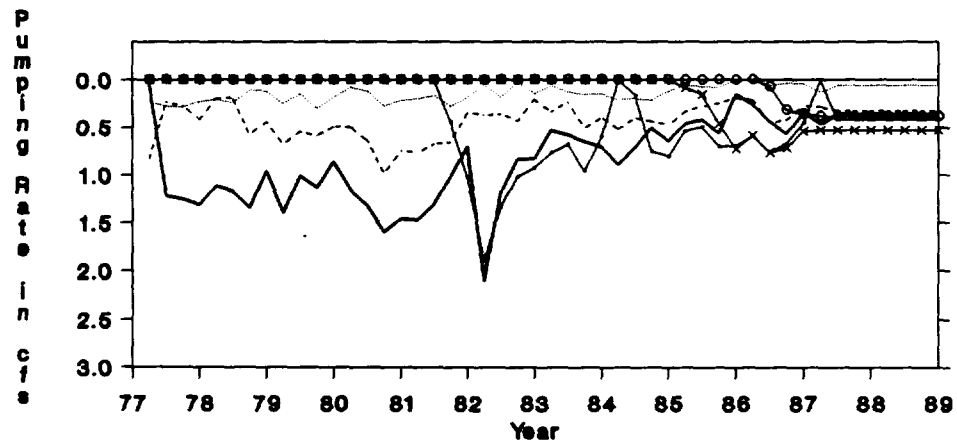
Cancer risks were estimated for each exposure pathway by summing the chemical-specific risks for ingestion and dermal absorption of contaminants. Contaminant dose estimates were derived using maximum contaminant concentrations (Table 10-1) and the equations shown in Table 10-5. Cancer risk is calculated by multiplying the contaminant dose by the slope factor. Also shown is the type of cancer and the EPA weight-of-evidence classification for each chemical. This classification is defined in the legend to Table 10-6.



# Sturgis Well Field RI/FS Pumping Records: 1977-1989 Municipal Wells

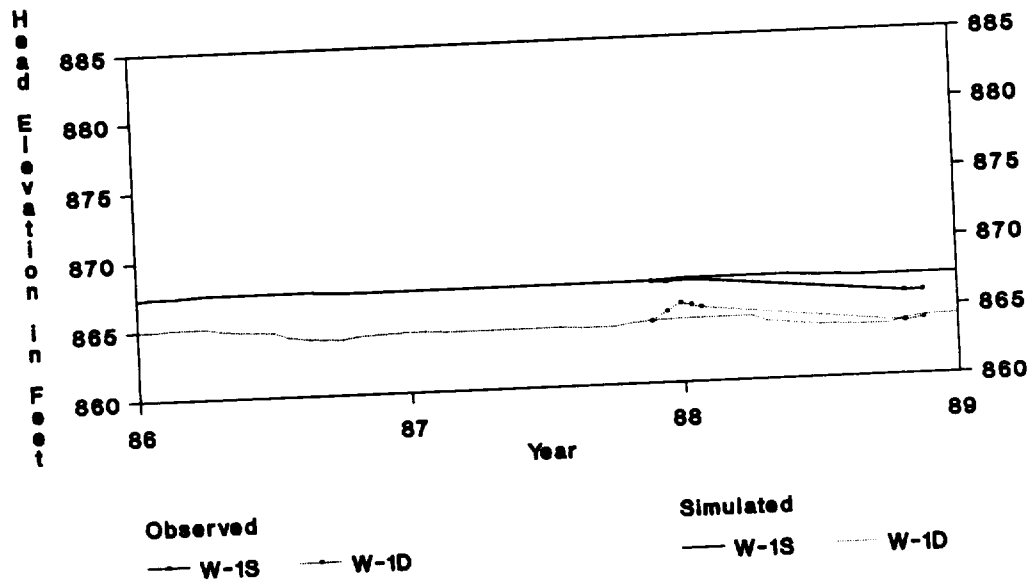


## Industrial Wells

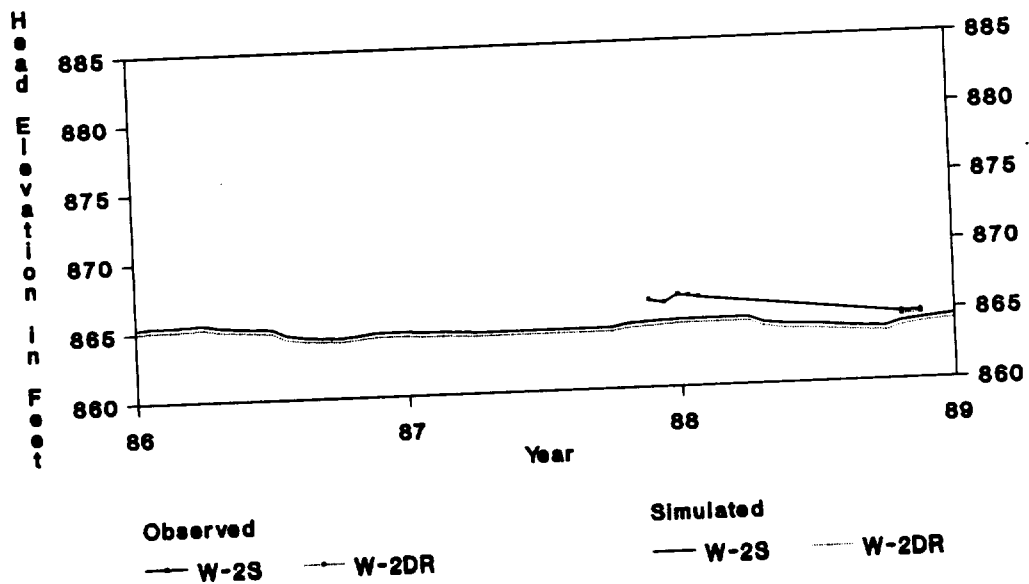


**Figure 1**  
Production Well Pumping Rates

# Sturgis Well Field RI/FS Observed vs Simulated Heads Well Nest W-1

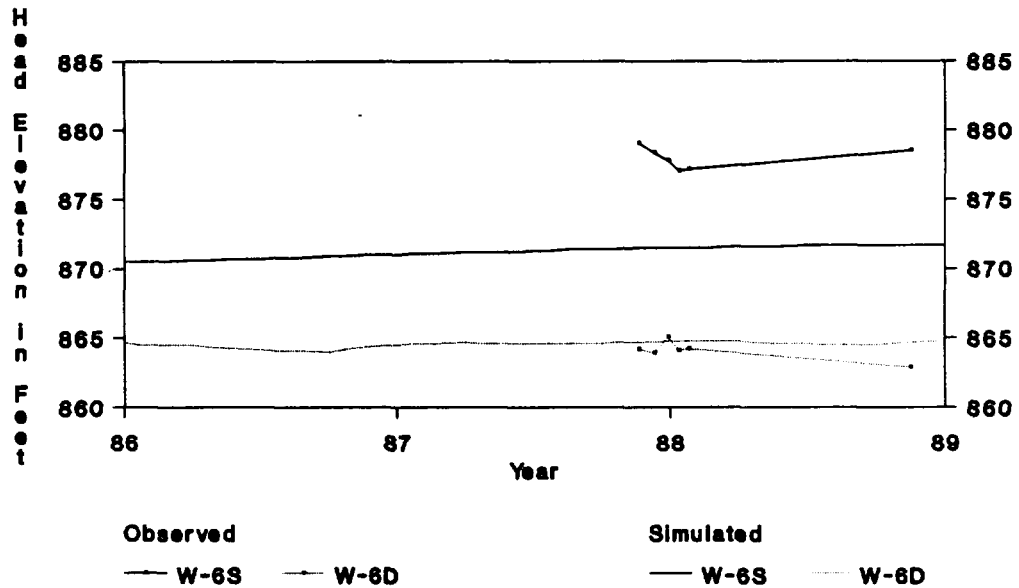


## Well Nest W-2

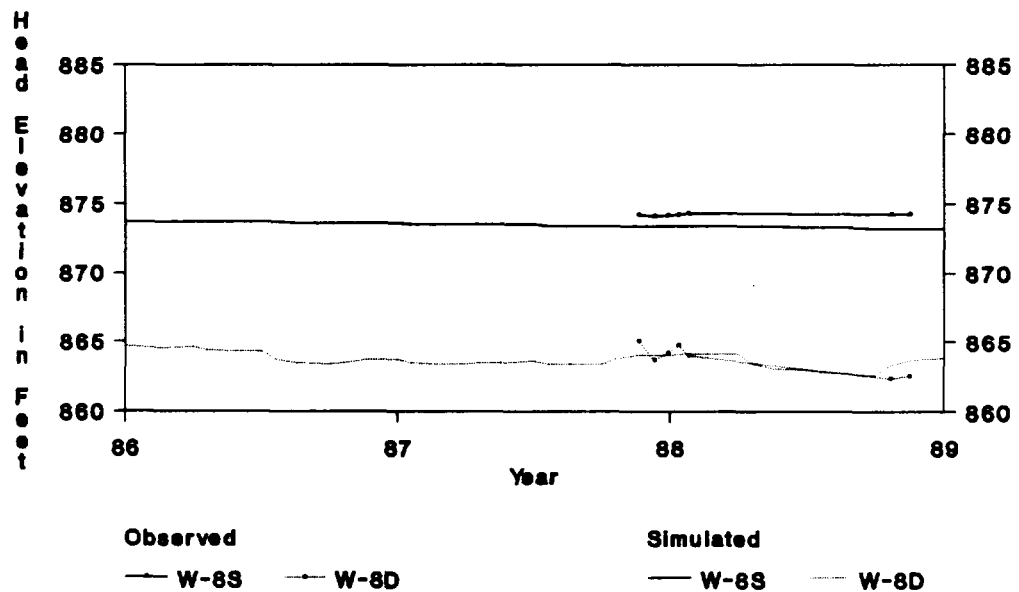


**Figure 2**  
Well Nests W-1 and  
W-2 Head History Graph

# Sturgis Well Field RI/FS Observed vs Simulated Heads Well Nest W-6

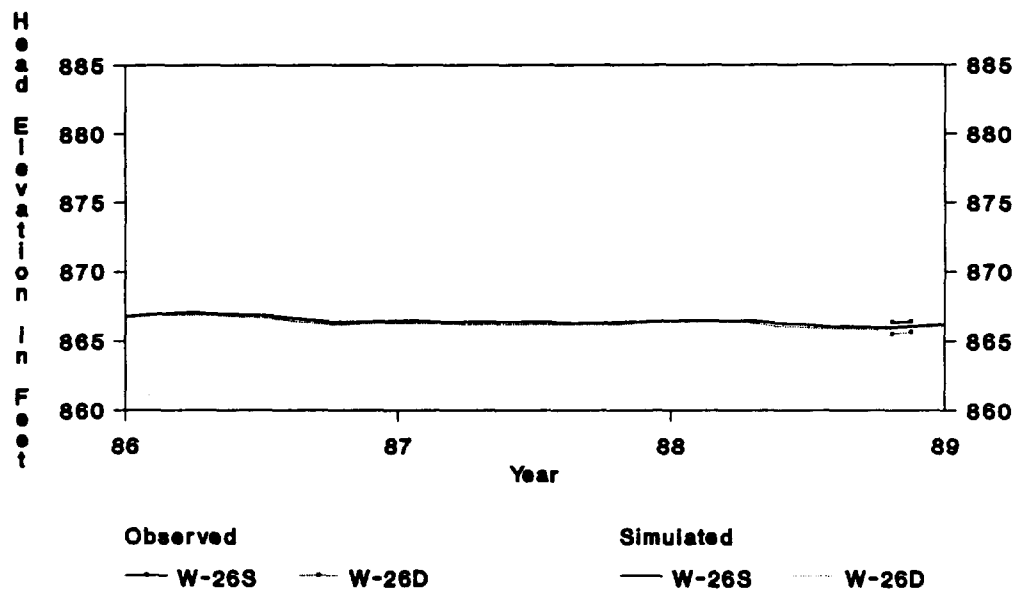


## Well Nest W-8



**Figure 3**  
Well Nests W-6 and  
W-8 Head History Graphs

# Sturgis Well Field RI/FS Observed vs Simulated Heads Well Nest W-26



**Figure 4**  
Well Nest W-26  
Head History Graph